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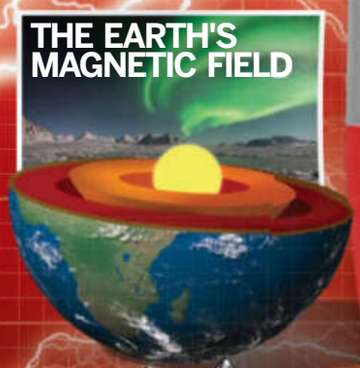
EXPLAINED! THE INVISIBLE FORCE THAT PROTECTS THE PLANET



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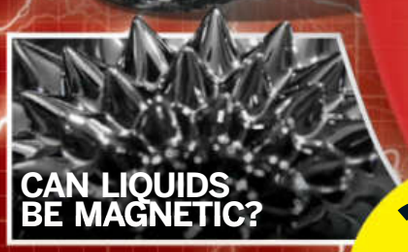

CAN LIQUIDS BE MAGNETIC?

316 AMAZING IMAGES & CUTAWAYS INSIDE

THE TESLA MODEL S

Inside the best all-electric car

NEW WONDERS OF THE WORLD

Hi-tech hypercars, bionic eyes, new species discovered & more!

+LEARN ABOUT

- JUMPING SUNDOGS
- CORDLESS PHONES
- JAPANESE CASTLES
- CASH MACHINES
- SPACE TOURISM
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- ASTEROIDS

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W. Britain

ZULU WAR

Presenting a selection of Zulu War figures; beautifully crafted and highly detailed models for the creation of inspired scenes.

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ISSUE 77

WELCOME

The magazine that feeds minds!

Page 12
Discover the amazing wonders of the world!

Sat in a science lesson and feeling the force between two magnets, was as close to becoming the superhero Magneto as I was ever going to get. It's no wonder that ancient people thought this mysterious force, that can attract as well as repel, was all down to magic. Today magnets are an essential part of technology, which you can see throughout this magazine, from the millions of teeny tiny magnets that make up the black strip on credit cards (page 48), to making hoverboards a reality (page 6).

Even the Earth is one giant magnet, powered by the iron core at the heart of the planet. Its magnetic field stretches out into space and shields us from the Sun's deadly solar storms. Without the magnetosphere, our green and blue marble would resemble Venus, our toxic twin, surrounded by a poisonous soup of chemicals. I didn't comprehend that mind-blowing fact while I was playing with iron filings and bar magnets in school, and I wish I could have read our cover feature back then. It makes you appreciate just how important and – ahem – *attractive*, this force truly is.

Jodie

Jodie Tyley
Editor

Meet the team...

Andy
Art Editor
The technology of videogames feature really caught my attention this issue. Who knew that so much goes into the games that we play?!

Jackie
Research Editor
After reading about the wildlife of the savannah, I'm sure my next trip will be an African safari. As sure as Kilimanjaro rises like Olympus above the Serengeti.

Siobhan
Production Editor
Learning 11 weird facts about foods made me look at food differently. It also means that I can blame eating too much bacon on science!

Jo
Features Editor
Where we're going, we don't need roads. We just need a magnetic track so we can use our Lexus hoverboards to get home and eat a rehydrated pizza.

Phil
Staff Writer
My next holiday won't be in space, but people will soon be able to holiday off-planet to see Earth's curvature and experience weightlessness.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

What is saliva and how can it benefit us? **Page 34**

How do weaver birds make amazing nests? **Page 67**

Why is the Tesla Model S the most high-tech car? **Page 54**

How do ATM machines deliver your money? **Page 48**

What are the most extreme temperatures ever? **Page 72**

What was life like inside a Japanese castle? **Page 76**

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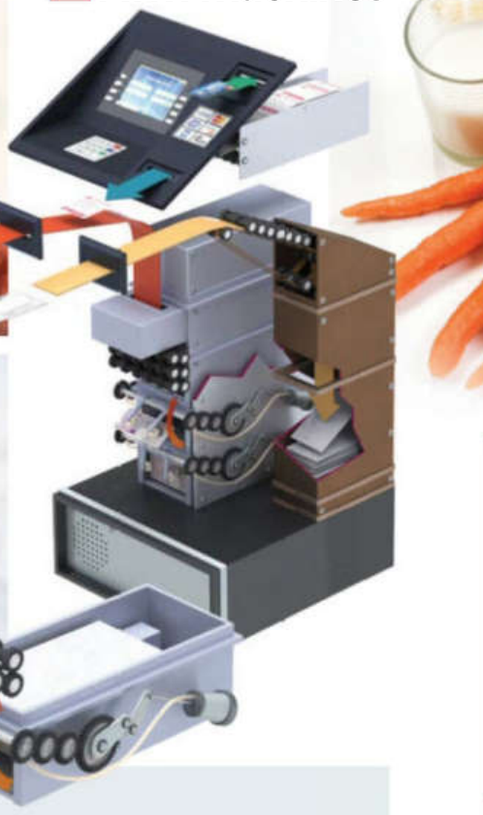

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Meet the experts...

Laura Mears
Everyday science is fascinating and the fact is that we use magnets daily from the minute we wake up, whether it's blow-drying our hair, checking our phone or opening our fridge. Laura explains all on page 24!

Gemma Lavender
This month, **All About Space** magazine's Gemma reveals NASA's plans to blast asteroids out of the sky and stop humanity going the same way as the dinosaurs.

Ella Carter
Animal expert Ella takes us on an African safari, showing us the spectacular sights. You'll discover how the amazing plants and animals, have adapted to survive in this challenging environment.

Lee Sibley
The Editor of **Total 911** swaps a Porsche for an electric motor when he test-drives the Tesla Model S. Find out why it's the most high-tech car on the road on page 54.

Dom Peppiatt
How many people does it take to make a videogame? **Games™**'s Dom goes behind-the-scenes to reveal all on page 40. You won't believe what's involved!

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REGULARS

The hoverboard is here!

Lexus unveils a frictionless board from the future

We may not have flying cars and self-lacing shoes just yet, but another of *Back To The Future II*'s predictions for 2015 is finally coming true. Car manufacturer Lexus has created a working hoverboard that uses electromagnetism to enable it to levitate 2.5 to five centimetres (one to two inches) above the ground. However, before you get excited about being able to hover your way to work or school, there is a catch. The board will only work over special magnetic tracks and can be used for just 20 minutes at a time. At the moment it is just a prototype and won't be going on sale any time soon, but now Lexus has proved it can be done, who knows what the future might hold.

Unlike its movie counterpart, the hoverboard can also work over water, provided that there is a magnetic track underneath

How it hovers

The Lexus Hoverboard uses magnetic levitation technology, working in a similar way to the Shanghai Maglev Train in China. Inside the board is an insulated core containing high temperature superconducting blocks (HTSLs). These are housed inside cryostats – reservoirs of liquid nitrogen that cool the superconductors to their optimum operating temperature of -196 degrees Celsius (-321 degrees Fahrenheit). Acting as electromagnets, the superconductors create a magnetic field that repels the permanent magnets in the track below, enabling the board to levitate at a consistent height and support up to 200 kilograms (440 pounds). After about 20 minutes, the liquid nitrogen evaporates and the superconductors warm up, causing the board to fall back to Earth. To test it out, Lexus built a special 'hoverpark' in Barcelona, Spain, with magnetic tracks hidden beneath it, and got pro skateboarder Ross McGouran to have a go.

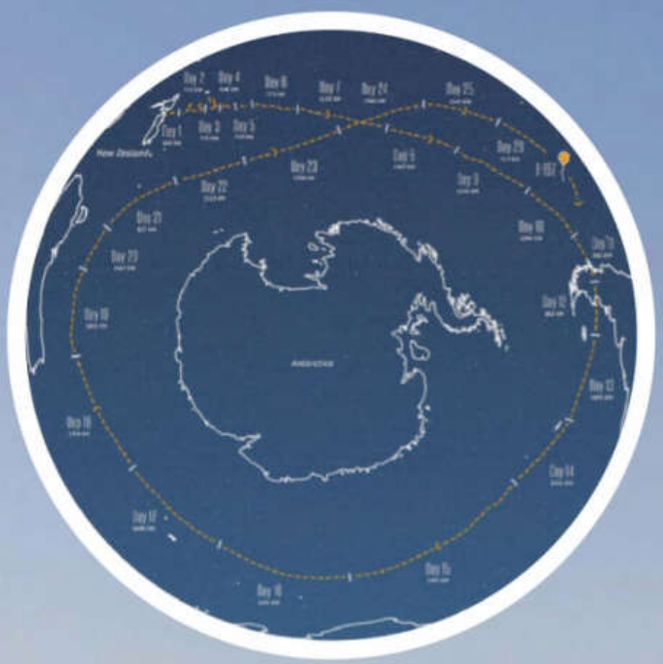
The hoverboard is about the size of a large skateboard and weighs about 11.5kg (25lb)

The smoke coming from the board is nitrogen vapour, created by the liquid nitrogen inside

Balloon-powered internet

Google plans to deliver web access from space

With two-thirds of the world's population unable to access their online search engine, Google has designed a network of balloons that can provide high-speed internet to remote areas without internet coverage. The idea involves telecommunications companies beaming 4G LTE wireless signals to the balloons, which will communicate with each other to pass the signal along. Each balloon will then act as a cell tower, relaying the signal to any LTE-enabled devices within an area around 40 kilometres (25 miles) in diameter below it. The project has already been successfully tested in New Zealand, but the next goal is to extend it to create a ring of uninterrupted connectivity in the Southern Hemisphere.



The balloons are designed to survive the extreme temperatures and UV radiation of the stratosphere

The Loon balloons

Each balloon has a small box containing a circuit board that controls the electronics, radio antennas for sending and receiving signals, and a battery that is charged by an array of solar panels for day and night use. The network of balloons will circle the Earth in the stratosphere on the edge of space. They will be about 20 kilometres (12 miles) up, high enough to avoid bad weather, wildlife and aeroplanes.

As the stratosphere features layers of wind that vary in speed and direction, software algorithms will be able to determine where each balloon needs to go and move it into the wind layer that can blow it the right way. Each balloon will last around 100 days in the stratosphere, before being brought back to Earth in a controlled descent for maintenance.

Project Loon will use high-altitude balloons to provide internet for all

Growing vegetables in space

NASA is testing gardening tech for Mars missions

Astronauts on board the International Space Station have had their first taste of food grown in space. The Veggie plant growth system used seed pillows, red, blue and green LEDs, and some water to produce a crop of romaine lettuce. Red and blue LEDs were used as they emit the wavelengths of light that have the greatest impact on plant growth, while green LEDs helped make them look more edible. The technology could one day be used to provide a nutritious and sustainable food source on deep space missions and even on Mars.

Growing food on Mars could have nutritional and psychological benefits for astronauts

'Shade balls' protect water from dust, rain, wildlife and chemical reactions

'Shade balls' protect LA water

96 million plastic balls help to keep drinking water safe

It may look like an attempt to create a giant ball pit, but city officials have a good reason for dumping millions of plastic balls into the reservoirs. The so-called 'shade balls' help block sunlight from reaching the water, preventing a hazardous chemical reaction. The water below contains both bromide and chlorine which, when exposed to sunlight, react to form bromate, a compound that increases the risk of cancer in humans. The balls also help prevent evaporation, helping to save 1 billion litres (300 million gallons) of water per year.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

A black hole has outgrown its own galaxy

Astronomers have located a freakishly large black hole that has expanded at such a rate that it has outgrown its galaxy. The super-sized black hole is located in galaxy CID-947, which is a whopping 11 billion light years away! The discovery backed what scientists had previously assumed, which was that black holes and their galaxies grow at the same rate.

Beer by-products can fuel cars

New Zealand has become the first country to start fuelling cars using a by-product of beer; specifically the yeast that is left over from the brewing process. The company in charge, DB Export, has produced an initial 300,000 litres (79,250 gallons) of Brewtroleum, which will be sold at 60 petrol stations across the North Island. It emits eight per cent less carbon than traditional petroleum and delivers the same performance.

Cockerels crow in pecking order

The sound of cockerels crowing in the early hours of the morning may appear to be completely random, but it actually follows a specific order. The most dominant cockerel of the bunch always crows first, announcing that morning has arrived, followed by the second most dominant and so on. Scientists believe that a rooster knows when to crow due to its own internal clock.

It's better to cook with lard than oil

Recent research suggests that frying with lard is better than using sunflower oil. When heated, oils rich in polyunsaturated fats (such as sunflower or corn oil) released high levels of potentially toxic compounds called aldehydes. Fewer aldehydes were produced when cooking with fats rich in monounsaturates or saturates, such as lard.

Dolphins have collapsible lungs

After studying six bottlenose dolphins, scientists have found out how these marine mammals avoid getting 'the bends' (decompression sickness) when resurfacing from the ocean's depths. It turns out that they have collapsible lungs, enabling them to inhale and exhale up to three times faster than humans. They are capable of exhaling a staggering 130 litres (34 gallons) of air per second. It's hoped that by studying dolphins more closely, scientists will be able to help people who suffer from 'the bends' when they are diving.

Bad sleep can change your genes

The occasional bad night's sleep may seem harmless, but a study has shown that this can affect our genes, particularly the ones that control our body's biological clock. This can change our body temperature, brain activity and even our appetite. Previous studies have shown that a lack of sleep negatively affects the body's metabolism; long-term sleep deprivation has been linked to obesity and may also contribute to the development of type 2 diabetes.

Solar-powered drone sets endurance record

The AtlantikSolar drone has performed a continuous flight of 81.5 hours, during which it travelled an incredible 2,316 kilometres (1,439 miles). This is the furthest any aircraft weighing less that 50 kilograms (110.2 pounds) has ever managed, and is the fifth longest flight by any aircraft, manned or unmanned.

Farming dates back 23,000 years

Until recently, historians believed that farming was first developed around 12,000 years ago, but a new discovery has found evidence to suggest that it has actually been around for almost twice as long. In a well-preserved hunter-gatherer settlement in northern Israel, called Ohalo II, scientists discovered the remains of crops and weeds. The presence of weeds is a sign that the inhabitants were attempting to cultivate the land, as they thrive in disturbed soil.

Trakkies never lose your valuables

These coin-sized devices are ideal for those of us that are always misplacing our possessions. The small circular gadgets, known as 'trakkies', alert their owner when they are about to leave the house without an important item, such as their wallet, keys or phone. The devices can be connected to a smartphone app that will give precise directions to the lost possession.

Watching thrillers boosts your memory

American scientists discovered that during a thriller movie's tense moments, our brains acquire a type of tunnel vision, enabling us to fully focus on the film's action. This form of intense concentration could be used to help increase memory recall, as the brain works to ignore irrelevant information and give its full attention to the matter in hand.

NEW WONDERS OF THE WORLD

THE EPIC BREAKTHROUGHS AND DISCOVERIES CHANGING LIFE AS WE KNOW IT

TELESCOPES SEARCHING FOR ALIEN LIFE

New initiative will scan ten times more sky than ever before

Leading scientists, including Professor Stephen Hawking, have launched the biggest-ever scientific search for signs of intelligent life beyond Earth. The Breakthrough Initiative will use two of the world's most powerful telescopes, the Parkes telescope in Australia and the Green Bank Telescope in the USA, to survey 1 million of our closest stars and listen for messages from the 100 closest galaxies. The antenna, or dish, of the radio telescopes collects incoming radio waves and reflects them back onto a receiver. The receiver and amplifier then boost the weak signal and are cooled to very low temperatures to minimise interference, as the movement of atoms in the metal can generate thermal noise. A recorder then keeps a record of the signal for astronomers to analyse.

"The telescopes will survey 1 million of our closest stars"

THE ROCKET THAT WILL TAKE US TO MARS

The world's most powerful rocket will usher in a new era of exploration

It has been over 40 years since the last NASA rocket took astronauts beyond low-Earth orbit, but the successor to the legendary Saturn V is now under construction. The Space Launch System (SLS) has been designed to send a manned Orion spacecraft beyond Earth's orbit, with the aim of reaching an asteroid and, eventually, Mars. Such deep-space missions require an incredibly powerful launch vehicle, and the 2.5-million-kilogram (5.5-million-pound) SLS will certainly be up to the job.

It can generate over 31 times the total thrust of a 747 jet, enough to propel 77 tons of cargo into space. There are three configurations planned for the rocket, enabling it to adapt to different space missions. The first, called Block 1, will stand at 98 metres (322 feet) tall, overshadowing the Statue of Liberty, but further versions will be even bigger and more powerful.

The first mission is scheduled for 2018 and will see the SLS send the Orion capsule into orbit around the Moon with no crew on board. If this initial test flight is successful, then a manned mission will follow in 2021. NASA are confident that, over the next few decades, the SLS will be sending humans further into space than ever before, and putting Mars within our reach by the 2030s.

Onboard the SLS

How NASA's Space Launch System will get humans to Mars

Orion spacecraft
The SLS will be able to propel up to four astronauts out of Earth's orbit onboard the Orion spacecraft.

Upper stage
The mighty 130-ton SLS configuration will feature an upper stage to provide the power to reach destinations beyond low-Earth orbit.

"The SLS can generate over 31 times the total thrust of a 747 jet"

Solid rocket boosters
Two boosters will burn five tonnes of propellant per second to provide 3.8mn kg (8.4mn lb) of thrust at liftoff.

Core stage
This enormous tank will store cryogenic liquid hydrogen, as well as liquid oxygen to fuel the engines.

RS-25 engines
The four engines will generate power equivalent to 5.5mn km (3.4mn mi) of residential streetlights.

THE LOST CITY OF ANGKOR

Laser technology reveals secrets hidden for centuries

The temple of Angkor Wat, one of the largest religious monuments ever constructed, stands alone in the middle of the Cambodian jungle. However, lidar technology has revealed that 900 years ago it was surrounded by a vast city. Lidar works in a similar way to radar by firing a million laser points at the ground from a helicopter every four seconds. The time it takes for each pulse to break through the trees, hit the ground and return is measured, and the resulting data enables any subtle indentations on the land to be mapped. This technique led archaeologists to find a grid of hidden streets, temples and waterways – evidence of a city that could have held 500,000 people!

Lidar technology revealed previously-unknown archaeological features in the land surrounding the famous temple. The black-and-white layer (left) shows the lidar data, detailing the hidden city of Angkor, while red lines indicate modern features such as roads and canals

3D PRINTING THAT IS CHANGING THE WORLD

Amazing applications for the latest technological breakthrough

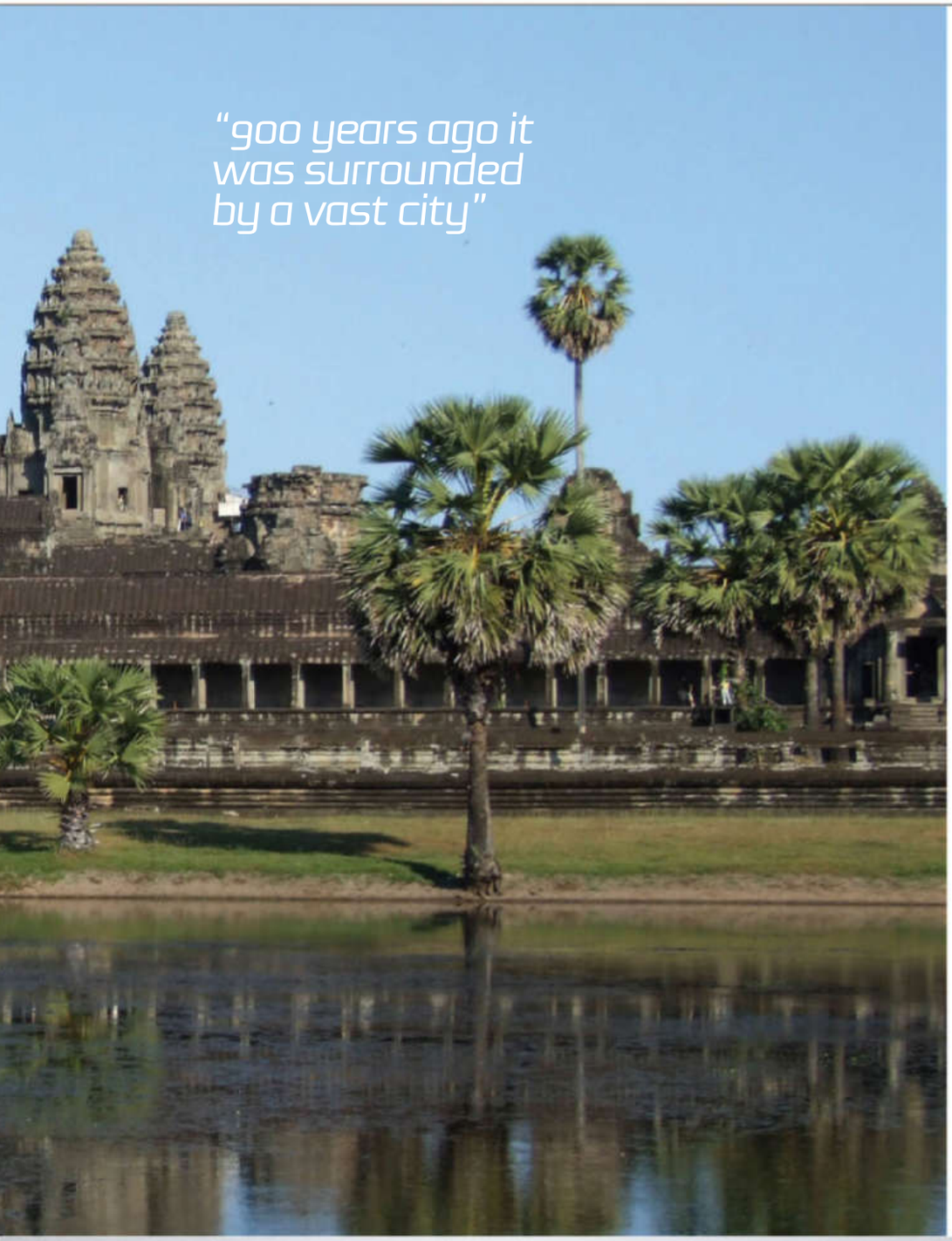
3D printing was first introduced in the late 1980s, but in recent years the technology has improved significantly. It's now possible to print a wide range of objects using a variety of materials, all from a digital file. There is no shortage of ground-breaking uses for this new approach to manufacturing.

Autonomous aircraft

Students at the University of Southampton have created the world's first entirely printed aircraft. The unmanned aerial vehicle is made from four major parts printed from nylon, which can be assembled without using any tools. The team hopes that their method will help revolutionise aircraft design.

Custom prosthetics

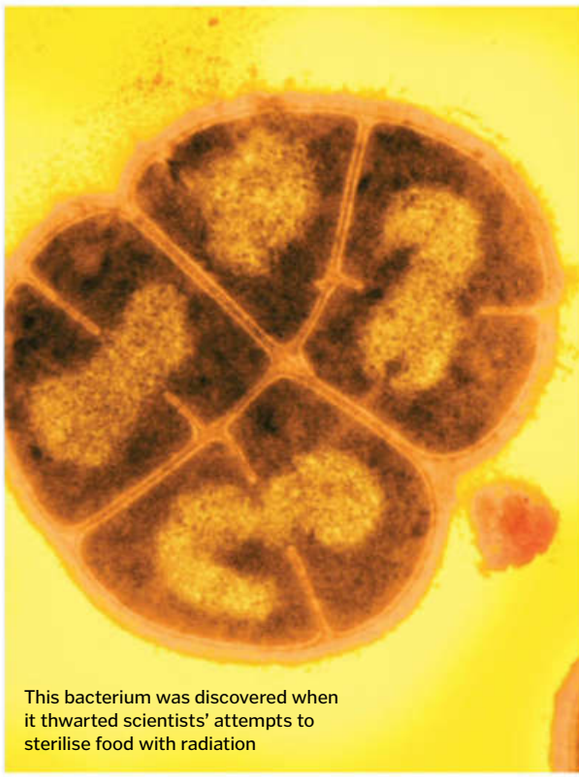
A global network called e-NABLE is giving people a helping hand, literally. It helps those in need of a prosthetic hand get in touch with people who have access to a 3D printer. They can then download various prosthetic designs and donate their time and resources free of charge.



WORLD'S TOUGHEST LIFE FORM

Hardy bacterium can survive 3,000 times more gamma radiation than humans

You might think *Marvel*'s Avengers are pretty tough, but they've got nothing on the superpowers of Deinococcus radiodurans. This microscopic bacterium can survive many harsh environments that would kill most other organisms, including a vacuum, extreme temperatures and acid. It also holds the title of the world's most-radiation resistant life form; when radiation slices up its DNA, it can stick itself back together again. It's thought that it evolved this skill as a defence to dehydration, which can also rip apart DNA.



This bacterium was discovered when it thwarted scientists' attempts to sterilise food with radiation

Efficient construction

The first 3D printed office building is due to be constructed in Dubai. A six-metre (20-foot) tall 3D printer will create it gradually layer by layer, and the 186-square-metre (2,000-square-foot) structure will be assembled on site in a matter of weeks. We could all have 3D printed buildings in no time!

Surgical aids

3D printing is not only useful for creating custom prosthetics and implants, it can also be used to help surgeons with complex procedures. 3D models of a patient's own anatomy can be created, enabling surgeons to plan their approach in great detail before they go into the operating theatre.

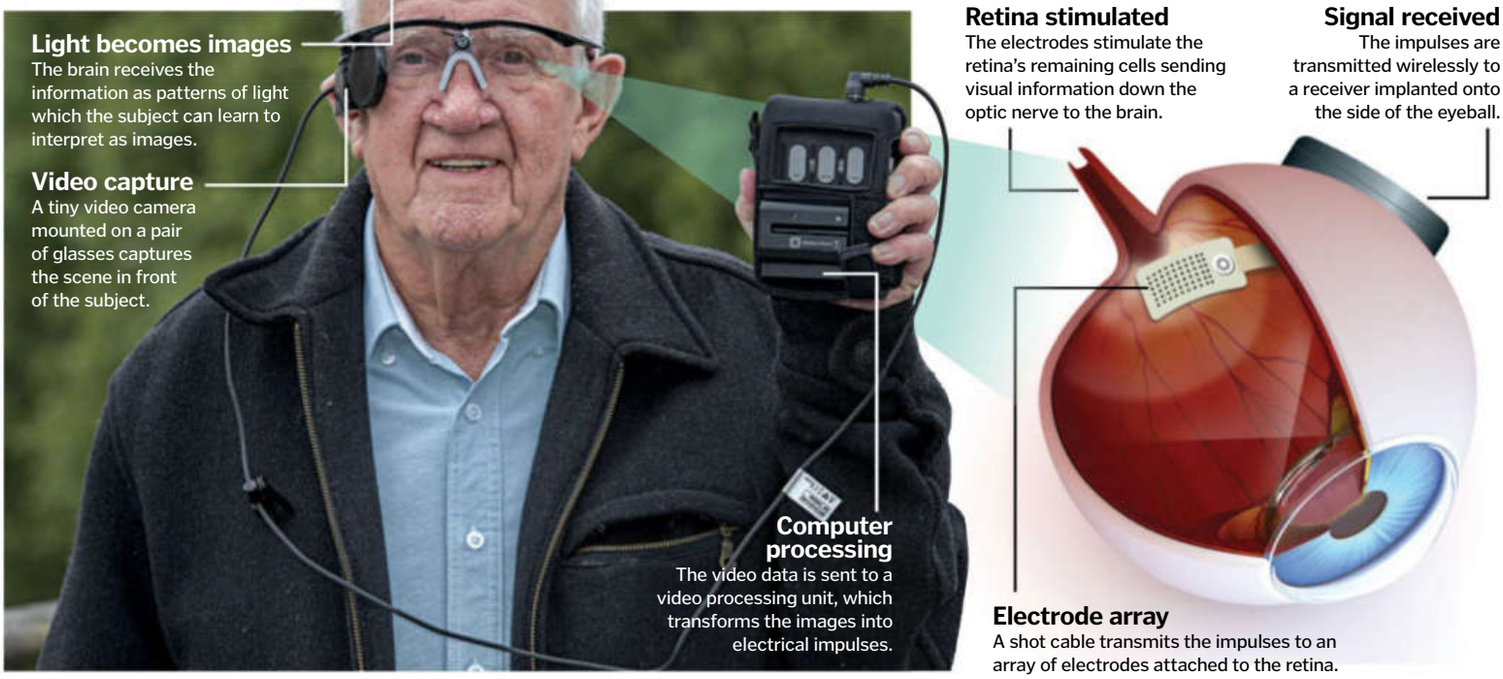
Preserving remains

When the grave of King Richard III was discovered beneath a car park in 2012, scans of his remains were used to print a 3D model of his skeleton. This has enabled researchers to study his anatomy in great detail, without the risk of any damage being caused to the actual bones.

THE BIONIC EYE THAT RESTORES SIGHT

Revolutionary implant has cured a common form of blindness

Age-related macular degeneration (AMD) is the most common cause of sight loss in the developed world. It occurs when cells in the middle of the retina become damaged, resulting in a central loss of vision. Until recently there was no treatment for the condition, but new technology has now provided a cure. An 80-year-old British man called Ray Flynn has become the first person to be fitted with a bionic eye to fix AMD. The Argus II implant, created by Second Sight, had previously only been used to cure a rare condition known as retinitis pigmentosa, but doctors now hope it can help the hundreds of thousands of people suffering from AMD. Before the procedure, Ray could only see clearly out of the corners of his eyes, but the implant has given him back his central vision and even enables him to see with his eyes closed. The Argus II is the first system in the world to combine artificial and natural eyesight, as electronic images in the centre of the eye merge with images from the surviving peripheral cells in the retina. Scientists are now working out how it can help patients who have been blind since birth, as they will have not yet learnt how to process images from the eye.



THE ULTRA-RARE HI-TECH HYPERCAR

Owners will have to take a special training course to drive this exclusive Aston Martin

If you have £1.5 million ($2.3 million) to spare, then you can get your hands on Aston Martin's new Vulcan. Underneath the front mid-engine, rear-wheel drive sports car's tough yet lightweight carbon fibre body, is an 800-horsepower 7.0-litre V12 engine that can go from 0-100 kilometres per hour (0-60 miles per hour) in under three seconds. The cockpit is home to a U-shaped smart steering wheel that features almost all of the controls, from starting the car to putting it in neutral, and the colours and trim can be infinitely customised. The car is too powerful for road use, so included in the price is a track driving course to get you started and a go in a racing simulator to refine your driving skills. However, with only 24 being made, you should get your order in fast.

THE LASER-ETCHED METAL THAT CAN BOUNCE WATER

New material could lead to rust-free metals and self-cleaning toilets

By using a powerful laser to create an intricate pattern on a metal surface, scientists have been able to create an extremely water repellent material that simply bounces droplets away. Currently, creating such surfaces has relied on applying coatings such as Teflon, but this new approach offers a more permanent solution that is not just hydrophobic, but superhydrophobic. To make droplets slide off of Teflon the surface must be tilted by 70 degrees, but the laser-etched metal only needs to be tilted by four degrees to remove the moisture. There are many potential applications for this new technology, including creating metals that don't rust or ice up, and easy-to-clean surfaces for medical and sanitary purposes, particularly in developing countries.

"Currently, creating such surfaces has relied on applying coatings such as Teflon, but this new approach offers a more permanent solution"

The superhydrophobic metal is impossible to get wet

A POTENTIAL CURE FOR GENETIC DISEASES

This ground-breaking technique enables genomes to be modified

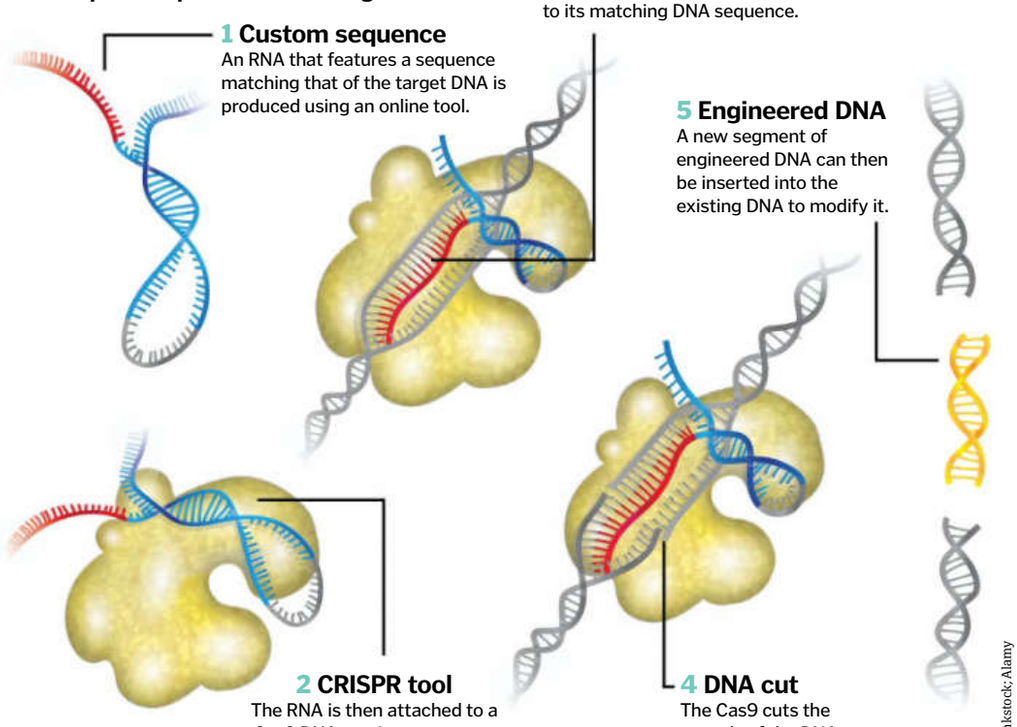
Editing DNA, the molecule that stores all of the genetic information that makes us who we are, is nothing new. However, a new tool now enables scientists to edit DNA with better precision and efficiency than ever before, and it has some potentially life-changing applications. It has already been used to create monkeys with targeted mutations and even prevent HIV infection in human cells, but it could eventually enable scientists cure any genetic disease.

The ground-breaking new tool is known as clustered regularly interspaced short palindromic repeats, or CRISPR for short, but it wasn't actually scientists that invented it.

CRISPR is a naturally–occurring system used by bacteria to protect themselves against viruses. When a bacterium detects the presence of virus DNA, it can copy segments of it as an RNA molecule. The RNA then joins forces with an enzyme called Cas9, and when it encounters a virus DNA with the same sequence, the Cas9 chops it up to disable it. Scientists have been studying this CRISPR/Cas9 system for many years, and have now worked out a way to use for editing the DNA within any cell belonging to any living thing in the world.

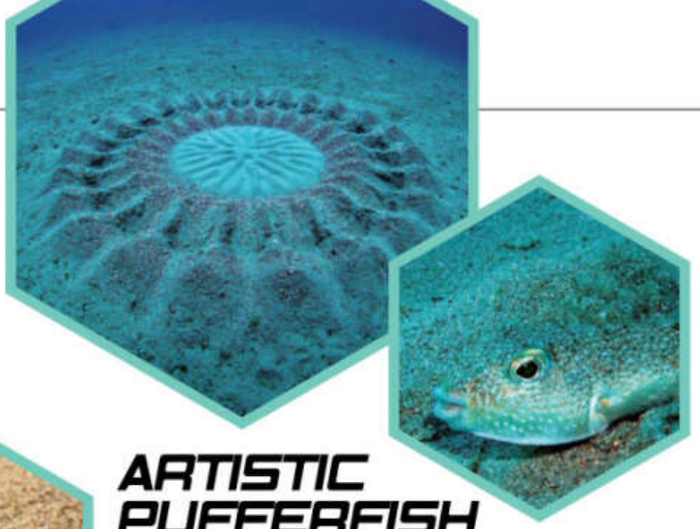
How CRISPR works

The simple new process for editing DNA



NEW SPECIES DISCOVERED

Introducing the unusual critters we've only just laid eyes on



CARTWHEELING SPIDER

Name: Cebrennus rechenbergi
Location: Morocco

This gymnastic spider has an ingenious method for escaping danger. If it finds itself in a threatening situation, it will first propel itself towards its attacker and assume a threatening pose. However, if the danger persists, it will cartwheel across the sand to escape, a method twice as fast as running. Tricky terrain isn't a problem, as the spider can cartwheel uphill and downhill as well as across flat ground, helping it navigate the desert sand dunes with ease. Its agile movements have even served as inspiration for a rolling robot.

ARTISTIC PUFFERFISH

Name: Torquigener albomaculosus
Location: Japan

For years, intricate geometric patterns had been spotted on the Japanese seabed with no clue as to how they got there. However, the mystery was solved when a new species of pufferfish was spotted creating the circular designs by wriggling through the sand. Their hard work is an attempt to attract females, but the beautiful structures also serve as a nest. The ridges and grooves around the edge of the circle minimise ocean current in the centre, helping to project the eggs from turbulent waves and possibly predators too.

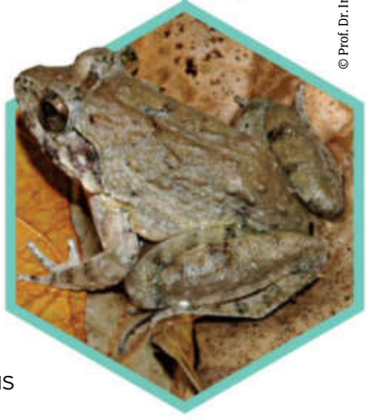
18,000
NEW SPECIES WERE DISCOVERED IN 2014

BONE-HOUSE WASP

Name: Deuteragenia ossarium
Location: China

This insect mother has come up with a very gruesome way to protect her offspring. First she constructs a nest in a hollow stem, creating several cells separated by walls of soil. She drags a paralysed spider into each cell and lays an egg on top of it, so that when the young wasp hatches its first meal is ready and waiting. Then, in the final cell, she plugs the entrance with several dead ants. As the ants are covered in chemicals that confuse and deter the wasp's predators, they make a secure front door to protect the young inside.

"It is the only species of frog in the world to give birth to live tadpoles"



TADPOLE-PRODUCING FROG

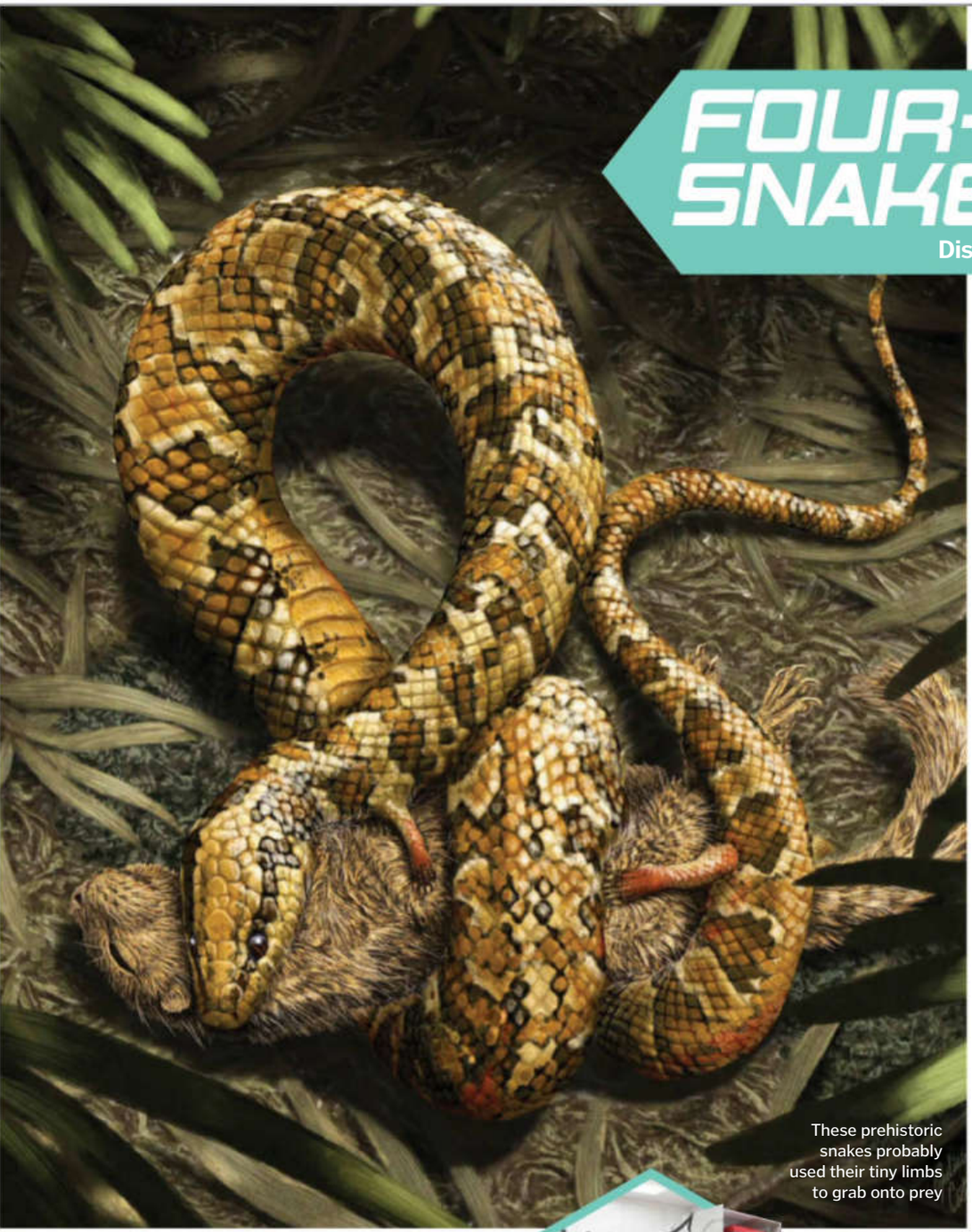
Name: Limnonectes larvaepartus
Location: Indonesia

Most female frogs lay eggs that are fertilised externally by a male, but this fanged amphibian has an entirely different approach. It is the only species of frog in the world to give birth to live tadpoles, depositing them straight into pools to grow. There are other frogs that have evolved internal fertilisation, but they all lay fertilised eggs or tiny froglets, rather than tadpoles. There is even some evidence to suggest that it's the job of the males to guard the tadpoles once they are born.

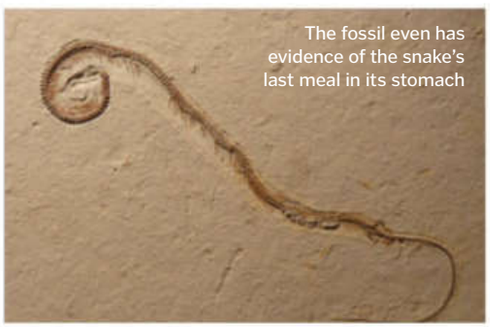
FOUR-LEGGED SNAKE FOSSIL

Discover the ancient snake with four limbs

The first known fossil of a four-legged snake has been found in Brazil, and it could hold the secrets of how and why serpents evolved from burrowing lizards. The 110-million-year-old fossil is the oldest definitive snake and dates from the Cretaceous period. It measures just 20 centimetres (eight inches) from head to toe, and has been categorised as a snake rather than a lizard based on several distinguishing features. For example, its body is longer than its tail, it has backward-pointing teeth and there is even an impression of a single row of belly scales on the surrounding rock. However, the snake's most remarkable feature has to be its two sets of one-centimetre (0.4-inch) long legs, complete with tiny hands and feet. The long fingers and toes seem to be specialised for grabbing, suggesting that when snakes stopped slithering and started walking, they began using their limbs to grasp prey or mates instead. This has inspired the snake's name Tetrapodophis amplectus: 'Tetrapodophis' means 'four-footed snake' and 'amplectus' means 'embrace'.



These prehistoric snakes probably used their tiny limbs to grab onto prey



The fossil even has evidence of the snake's last meal in its stomach

A HOTEL STAFFED BY ROBOTS

Japan's low-cost hotel replaces humans with a talking dinosaur

As you approach the check-in desk at Japan's Henn na Hotel, you will be greeted by an English-speaking dinosaur wearing a hat and bow tie. This unusual receptionist is just one of the many robots that make up the majority of the hotel's staff. Called 'Weird Hotel' in English, it makes use of all sorts of clever technology. Self-service check-in and check-out mean you don't have to wait in line, and there's no danger of losing your room key as facial recognition software lets you into your room. There's also an automated luggage trolley to carry your bags, and once you are in your room, you can speak to another robot to control the lights and temperature, and get weather updates.

The cloakroom robot can store your luggage for you

The reception is manned by an English-speaking dinosaur, a Japanese-speaking female android and a third 'information robot'

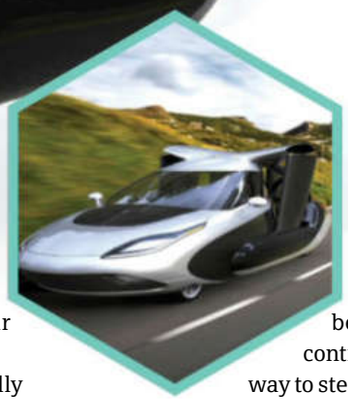
FUTURE WONDERS OF THE WORLD

"In flight, the propellers fold away and it can cruise at 200 miles per hour"

The TF-X's electric motors are powered by a 300-horsepower engine

THE FLYING CAR

Autonomous TF-X can take off and land anywhere



The car can recharge its batteries either from its engine or via a charging station

Being able to soar above traffic jams and land right outside the office would certainly make the morning commute more enjoyable, and this dream looks set to become a reality in the not-so-distant future. Looking like something from science fiction, the TF-X flying car is currently being developed by Terrafugia.

The autonomous vehicle will be able to fit inside a standard garage, carry up to four people, and learning how to operate it takes around five hours. The driver can input their desired landing zone, the car's wings will unfold and two propellers will lift it vertically from any level clearing with a 30-metre (100-foot) diameter. During flight, the propellers fold away and it can cruise at 322 kilometres (200 miles) per hour with a range of 805 kilometres (500 miles).

The TF-X will automatically avoid air traffic, bad weather and restricted airspace, or it can be manually controlled in a similar way to steering a car. Then, once back on land, it can turn back into a car again in seconds. The TF-X is estimated to be in development for a further eight to 12 years, but if you just can't wait that long, then the company's less easy-to-operate Transition flying car is expected to be available for purchase at a much sooner date.

THE ELEVATOR THAT CAN MOVE SIDEWAYS

New cableless technology could lead to even taller skyscrapers

In today's fast-paced world, waiting for an elevator can be frustrating, but new technology could cut down your wait time to as low as 15 seconds. In German tech company ThyssenKrupp's vision for the future, elevator shafts will carry multiple cabins so the next one will never be far away. Instead of using a cable system, each elevator will feature a linear motor, enabling it to operate in a similar way to a maglev (magnetic levitation) train. This means that it could move horizontally as well as vertically, and the cabins could travel in a loop. The company will start testing its MULTI system in 2016, and hopes it will lead to taller and more creatively shaped buildings.

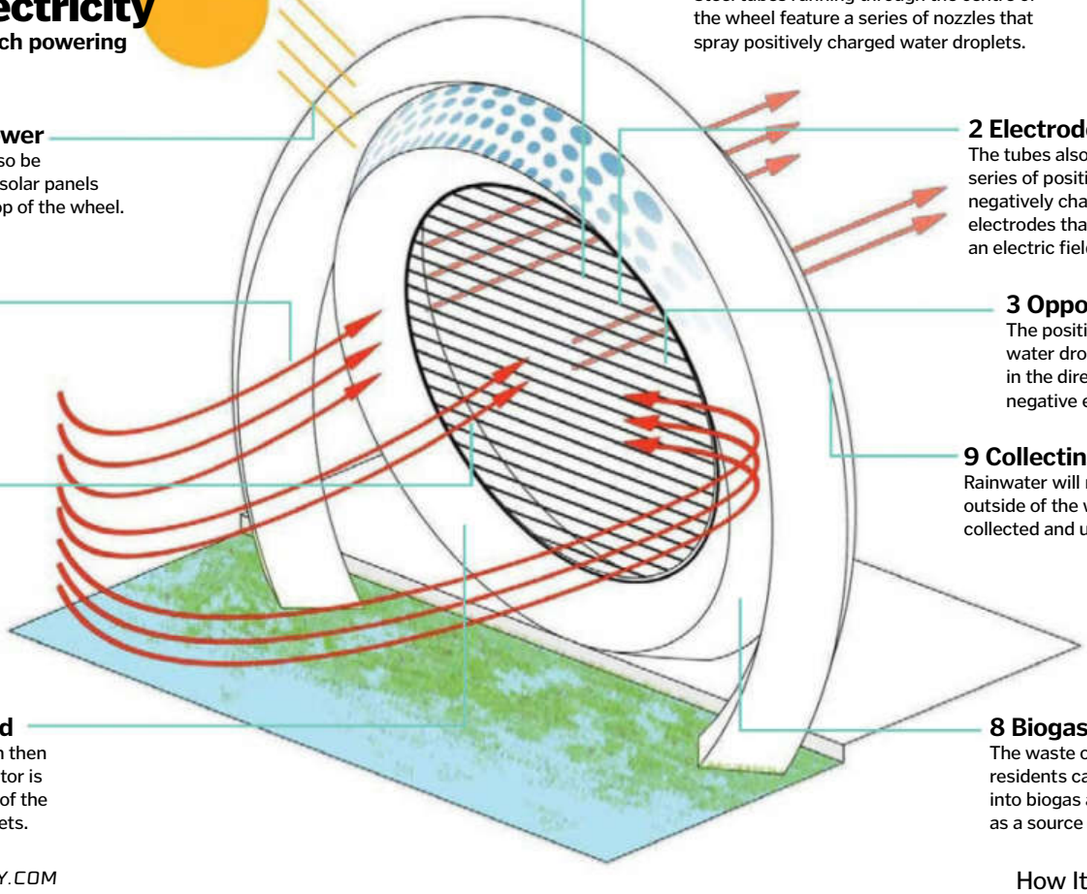
THE WIND TURBINE YOU CAN LIVE IN

Windwheel generates power with no moving parts

While large spinning turbines already enable us to harness wind power, living in close proximity to them can be a noisy affair. That could be about to change, however, as innovative new technology can make the process much quieter – enough for it to be installed inside an apartment block. This new system is called Electrostatic Wind Energy Converter (EWICON) and works by using the wind to displace charged particles in the opposite direction of an electrical field. It has been proven to work on a small scale, but now engineers are working on supersizing it for use in Holland's next landmark, the Dutch Windwheel. The striking structure – expected to be completed by 2025 – will stand 174 metres (570 feet) tall in Rotterdam harbour, making it look as though it is floating on the water. Around the central structure that harnesses wind power, will be an inner ring containing 72 apartments, 160 hotel rooms, shops and a restaurant. The outer ring will feature 40 cabins running on rails around the structure, forming a giant observation wheel that gives visitors spectacular views over the city and takes them beneath the water for an interactive cinema experience.

How the Windwheel generates electricity

The renewable energy tech powering Holland's next attraction



1 Nozzles
Steel tubes running through the centre of the wheel feature a series of nozzles that spray positively charged water droplets.

2 Electrodes
The tubes also feature a series of positively and negatively charged electrodes that create an electric field.

3 Opposites attract
The positive charge of the water droplets pulls them in the direction of the negative electrodes.

4 Wind power
The wind then pushes the droplets in the opposite direction, so they move towards the positive electrodes.

5 Potential energy
This increases the potential energy of the droplets, much like pushing a rock up a hill against the force of gravity.

6 Energy collected
The potential energy can then be collected, as a capacitor is charged by the removal of the positively charged droplets.

7 Solar power
Energy can also be generated by solar panels installed on top of the wheel.

8 Biogas
The waste of the building's residents can be turned into biogas and harnessed as a source of energy.

9 Collecting rainwater
Rainwater will run down the outside of the wheel to be collected and used as tap water.

OUT OF THIS WORLD WONDERS

EARTH 2.0

Our planet's big cousin could be habitable

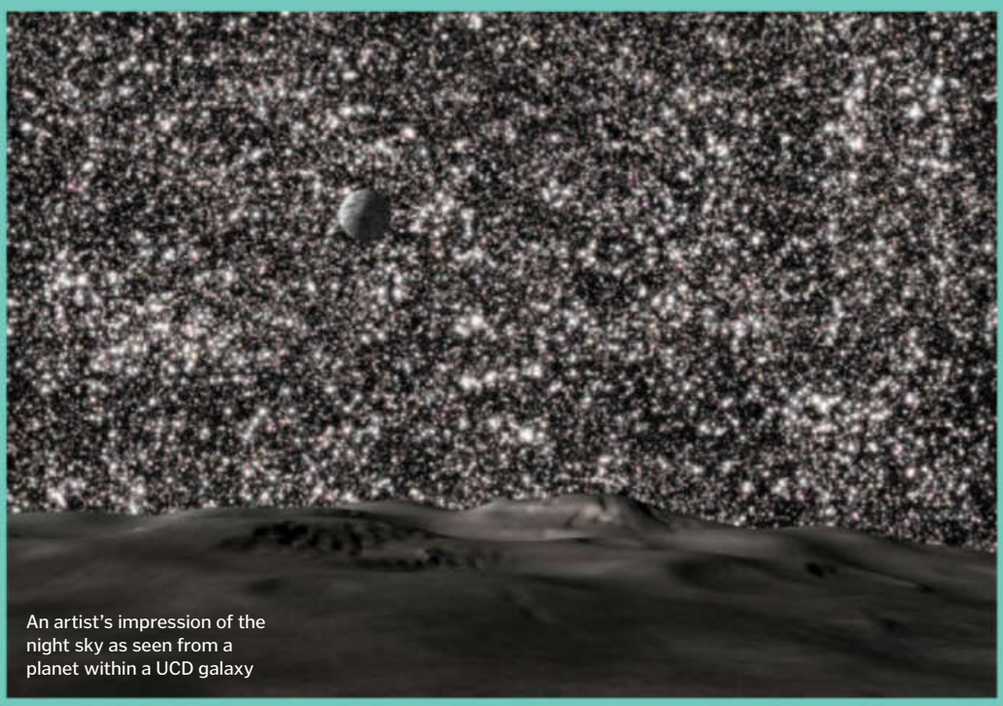
On its hunt for exoplanets with the potential to support life, NASA's Kepler space telescope has found a planet and star that most closely resemble our own Earth and Sun. Kepler 452b is the smallest planet to date to be discovered orbiting within the habitable zone of a Sun-like star, where it is warm enough for liquid water to potentially pool on the surface. The planet was found 1,400 light years away from Earth in the Cygnus constellation, and while its mass and composition have not yet been determined, previous research suggests that planets of this size have a good chance of being rocky. In addition, its host star, Kepler 452, has the same temperature as our own Sun, despite being 20 per cent brighter and having a diameter that is ten per cent larger. "We can think of Kepler 452b as an older, bigger cousin to Earth," said Jon Jenkins, Kepler data analysis lead at NASA's Ames Research Center. "It's awe-inspiring to consider that this planet has spent six billion years in the habitable zone of its star; longer than Earth. That's substantial opportunity for life to arise, should all the necessary ingredients and conditions for life exist on this planet."

"We can think of Kepler 452b as an older, bigger cousin to Earth"

EARTH VS KEPLER 452B

EARTH	KEPLER 452B
365 DAYS IN A YEAR	385 DAYS IN A YEAR
4.54 BILLION YEARS OLD	6.00 BILLION YEARS OLD
12,756 KILOMETRES IN DIAMETER	20,410 KILOMETRES IN DIAMETER
149.6 MILLION KILOMETRES FROM NEAREST STAR	157.0 MILLION KILOMETRES FROM NEAREST STAR

© NASA/JPL-Caltech/T. Pyle



An artist's impression of the night sky as seen from a planet within a UCD galaxy

THE DENSEST GALAXY IN THE UNIVERSE

This galaxy is 15,000 times denser than the Milky Way!

If you were to stand within the M59-UCD3 galaxy and look up at the night's sky, you would see a spectacular display of more than a million stars, compared to the mere thousands visible from Earth. The galaxy is one of two new systems to be discovered by a pair of students at San José State University, and they belong to a new class of galaxies known as ultra-compact dwarfs (UCDs). M59-UCD3 is around 200 times smaller than our own Milky Way, but has a stellar density 10,000 times larger, while the second galaxy, M85-HCC1, is denser still. It is believed that they were originally much bigger galaxies, whose fluffy outer parts were stripped away, leaving their dense centres behind.

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THE POWER OF MAGNETISM

EXPLAINED! THE INVISIBLE FORCE THAT PROTECTS THE PLANET

1912
The year that the first superconducting magnet was made

-197°C
The temperature of the magnets in Lexus' hoverboard prototype

603 km/h
The record-breaking top speed of Japan's maglev train

Fe, Ni, Co
There are three common magnetic elements: iron, nickel, and cobalt

People have known about magnetism for thousands of years, but for centuries it was poorly understood. Ancient civilisations in Greece and China had access to a natural magnetic rock called lodestone, and they first began to understand its properties around 2,000 years ago. Soon people were using lodestone to attract iron objects, and later to build compasses pointing to Earth's magnetic poles.

During the Middle Ages, compasses arrived in Europe and sailors took them to the seas. In 1492, magnetism led Christopher Columbus to the New World. However, it wasn't until 1600 that English scientist William Gilbert realised that compasses point north because the Earth is a magnet; and so the science of magnetism began to unravel.

In 1820, Danish scientist Hans Christian Ørsted noticed that electricity travelling through a wire generated a magnetic field. Other scientists tried coiling the wire and found that for every turn, the magnetic field got stronger. Then, five years later, William Sturgeon wrapped the wire around a piece of iron, creating the first practical electromagnet, which led to the invention of the electric generator and motor.

Today, magnets are everywhere. But how do they actually work? Join us as we find out.

WHAT MAKES A MATERIAL MAGNETIC?

To understand why, you have to look at their electrons

Electricity and magnetism are linked. As positively or negatively charged particles move, they generate a magnetic field that circles around the direction of the current. This happens when charged metal ions swirl around in the Earth's core, charged particles zip through the interior of the Sun and electrons race along an electrical wire. Magnetic fields affect other charged particles that attempt to travel through, forcing them to change the direction they are travelling in.

This also happens at the subatomic scale. We know that magnetic fields are generated when charged particles move, but they don't have to be travelling along an electrical wire, even tiny movements are enough. Every electron in every atom is spinning on its own axis, and because of its negative charge, this movement generates a 'magnetic moment'. Each electron is essentially a tiny magnet.

In most materials, the electrons are in pairs – one spinning 'up' and one spinning 'down' – so their magnetic moments cancel each other out. However, in other materials there are electrons without a partner. If enough of these unpaired electrons are spinning in the same direction, the combined effect of their individual magnetic moments generates an external magnetic field.

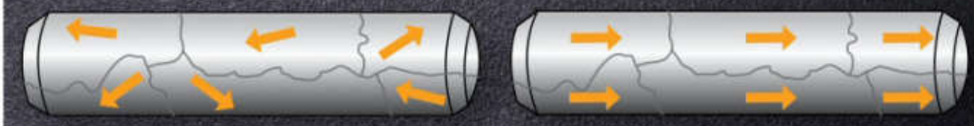
Even if the electrons aren't all spinning in the same direction, the fact that they are without a partner has important effects on the behaviour of the material. Depending on their structure, materials respond differently to magnets. If all of the electrons are paired, materials are diamagnetic – they are not attracted to magnetic fields. In fact, they weakly repel them. This applies to most of the elements, including metals like gold and silver, and non-metals like wood or petroleum.

If a few of the electrons are unpaired, materials are paramagnetic – they are ever so slightly attracted to magnetic fields. Two examples include magnesium and oxygen. Finally, if there are lots of unpaired electrons, materials are ferromagnetic – strongly attracted to magnetic fields and able to make magnets. The key ferromagnetic elements are iron, nickel, and cobalt.

Our ancestors used the naturally magnetised mineral magnetite to make primitive compasses

What makes a magnetic material a magnet?

The reason why every lump of iron doesn't stick to the door of your fridge

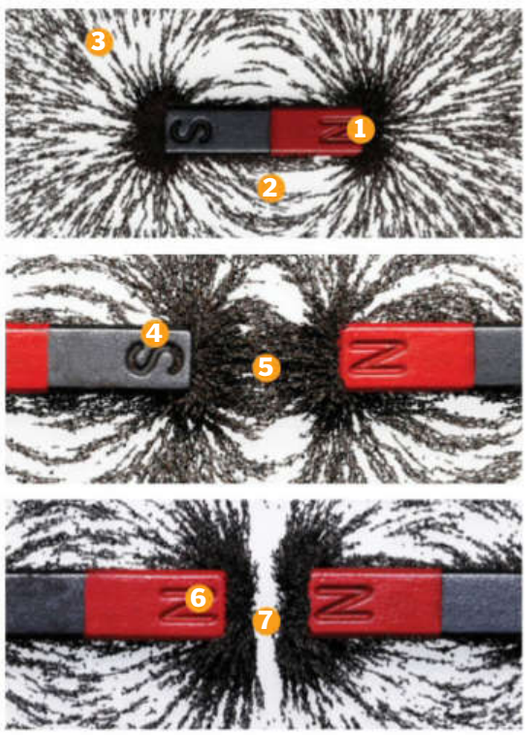


In magnetic materials, patches of unpaired **electrons spin in the same direction. Their combined** magnetic moments generate local magnetic fields called domains, but because each domain points in a different direction, they cancel each other out.

If a really strong magnetic field is applied, the **local magnetic domains can all be pulled into** the same alignment. When combined together, the effects of all of the domains are enough to generate an external magnetic field.

Magnetic fields

Magnetic fields are generated when charged particles move. Inside a magnet, lots of electrons have been forced to line up, all spinning in the same direction. The combined effect produces an invisible external magnetic field that can be observed using iron filings.



1 Poles
A magnetic field has two poles, usually called north and south.

2 Magnetic field
The field around the magnet extends in all directions, influencing any moving charged particle in the area.

3 Field lines
Iron filings are magnetic. When placed near a bar magnet, they line up along the invisible magnetic field lines.

4 Opposites attract
When two magnets are facing in the same direction, the interaction between their magnetic fields pulls them together.

5 In line
The iron filings line up between the north and the south pole, aligning their own magnetic fields to the fields of the magnets.

6 Same poles repel
When the like poles of two magnets face each other, the interaction results in repulsion.

7 Nowhere to go
The iron filings are forced apart by the two interacting magnetic fields.

WHY ARE MAGNETS SO IMPORTANT?

They guided early explorers and today we would be completely lost without them

Electromagnets are responsible for generating the vast majority of our electricity. From coal and oil, to wind and waves, most of our power stations generate a current using the same basic principles. Something (steam, water, wind) spins a turbine, which is linked to a generator by an axle. As the axle turns, it spins a coil of metal inside a magnetic field (or vice versa) and produces a current.

Converting the electrical energy back into mechanical energy also uses magnets – the process is simply reversed. Magnets in electric motors turn car wheels, washing machine drums, fridge compressors, electric drills and many more. Magnets are used to produce the vibrations needed to transmit sound from a headphone or speaker. They also encode data on the magnetic strips of credit cards and hold information stored on hard drives.

They are used by scientists to study the universe, bending the path of particles at facilities like CERN, and they are used in the lab to investigate chemical structures via nuclear magnetic resonance (NMR) imaging. In hospitals, this same technology enables doctors to look inside the human body without the need for surgery. Our world today would be unrecognisable without magnets!

Industrial magnets

Magnets are commonly used in industry to remove magnetic impurities known as 'tramp metal'. In food and medical manufacture, magnets can remove dangerous contaminants, including loose bolts or metal flakes from the machines. In the mining industry, large magnets are suspended over the belts to capture iron tools, nails, or other debris that might damage the processing machinery. In glass, ceramics and plastic manufacture, magnets ensure that the final product is free from any iron-related imperfections that could be present.

Electric current
Current flows through the coiled wires in the electromagnet, generating a magnetic field.

Electromagnet
Coils of wire are used to create a large electromagnet, powerful enough to lift heavy chunks of scrap metal.

Recyclables
Alloys of iron and nickel are used in thousands of everyday products, and can be easily recycled to make more.

Scrap
Iron, nickel and steel are all magnetic, so scrap containing any of these metals will be attracted to the magnet.

On or off
The crane driver can lift and drop the metals by simply switching the electromagnet on or off.

Separation
Non-magnetic materials are left on the ground, helping to separate the scrap that can be reused or recycled.

Magnetic recording

Magnetic tape was first invented to store sound, but was later adapted for videos and computers

Magnets at the LHC

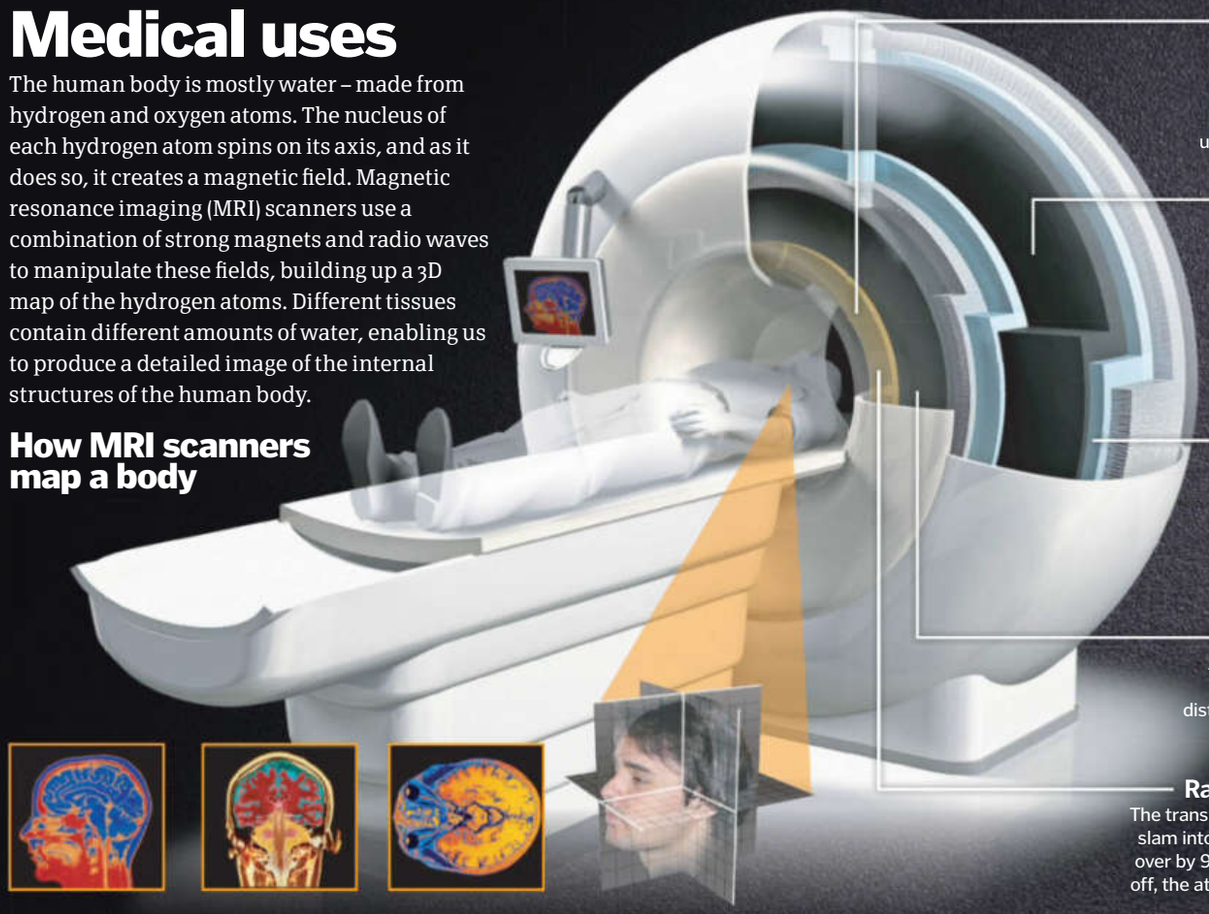
The Large Hadron Collider is home to some of the most powerful electromagnets in the world

Some of the electromagnets at the Large Hadron Collider can produce magnetic fields more than 100,000 times more powerful than Earth's. Over 1,200 lattice magnets are used to bend the path of the particles as they hurtle around the ring, and each weighs as much as a lorry. As the particles enter the detectors, their paths are deflected by more magnets, one of which – known as the Compact Muon Solenoid – is currently the largest solenoid magnet in the world.

Medical uses

The human body is mostly water – made from hydrogen and oxygen atoms. The nucleus of each hydrogen atom spins on its axis, and as it does so, it creates a magnetic field. Magnetic resonance imaging (MRI) scanners use a combination of strong magnets and radio waves to manipulate these fields, building up a 3D map of the hydrogen atoms. Different tissues contain different amounts of water, enabling us to produce a detailed image of the internal structures of the human body.

How MRI scanners map a body



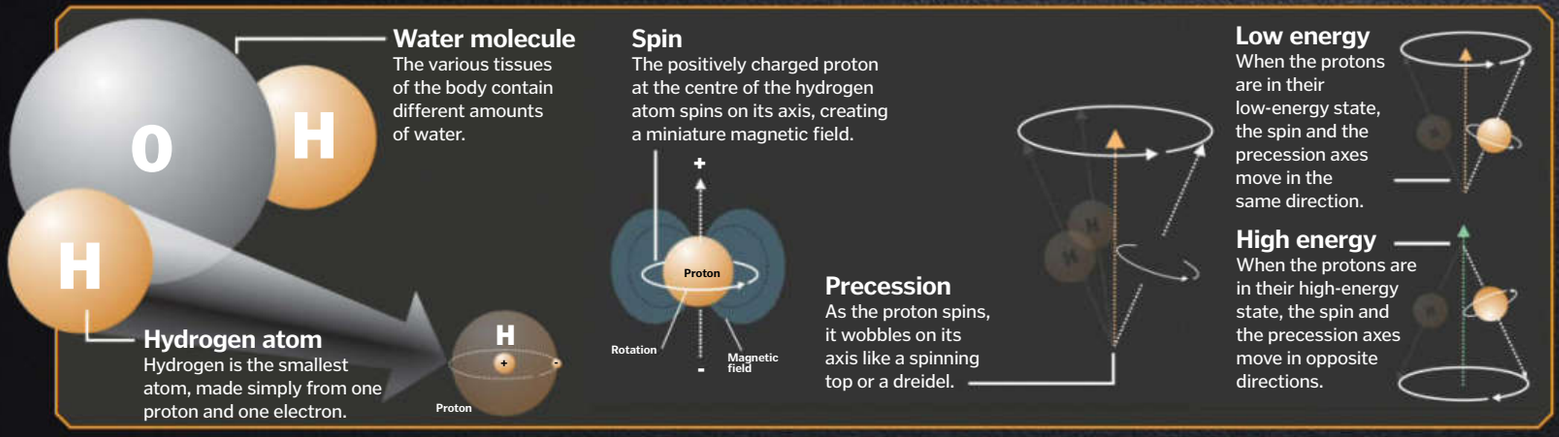
Radiofrequency receiver
The energy released by the rotating hydrogen atoms is detected by the radiofrequency receiver. The data is then sent to a computer, where it is used to build a 3D image of the body.

Superconducting magnet
A niobium-titanium superconducting magnet can produce a powerful magnetic field. The field aligns the hydrogen atoms in the patient's body.

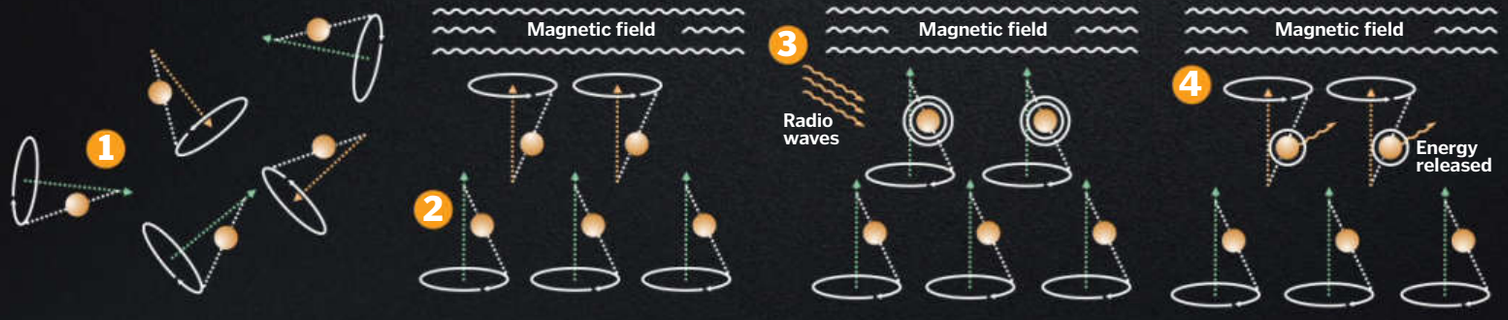
Cooling systems
The magnet must be maintained at a temperature below -269 degrees Celsius (-452 degrees Fahrenheit). This is done using cryogenic liquids – a supply of liquid helium.

Magnetic gradient coils
A second set of magnets are used to create another magnetic field. This distorts the main field, making patterns to map the signal's 3D position.

Radiofrequency transmitter
The transmitter produces radio waves, which slam into the hydrogen atoms, flipping them over by 90 or 180 degrees. When it switches off, the atoms spin into line, releasing energy.



Hunting for atoms



1 Hydrogen in the body
Normally, the hydrogen atoms inside the body all point in random directions.

2 Strong magnetic field
Inside the scanner, the field generated by the superconducting magnet causes the precession axes of the hydrogen atoms to line up.

3 Radiofrequency stimulation
The radiofrequency transmitter produces radio waves, which transform low-energy protons into high-energy protons.

4 Relaxation
When the radio wave transmission stops, the high-energy protons release energy and switch back to their previous state.

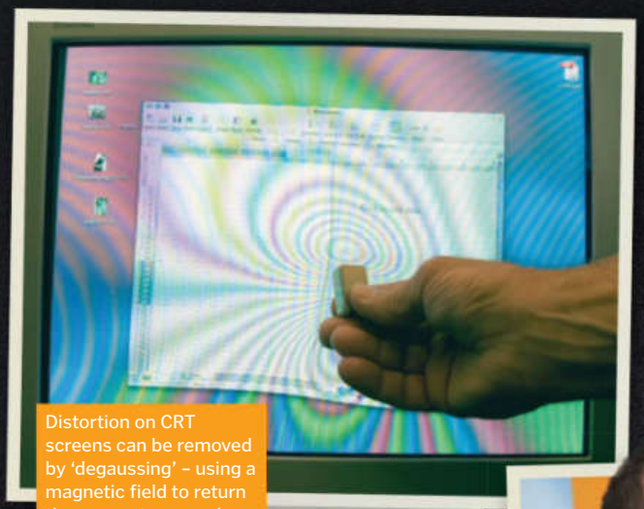
5 Creating the image
The pattern of radio waves, released when the protons switch from high to low energy, can be used to build a 3D image.

MAGNETS 101

Your curious questions about magnets answered!

Why do magnets disrupt screens?

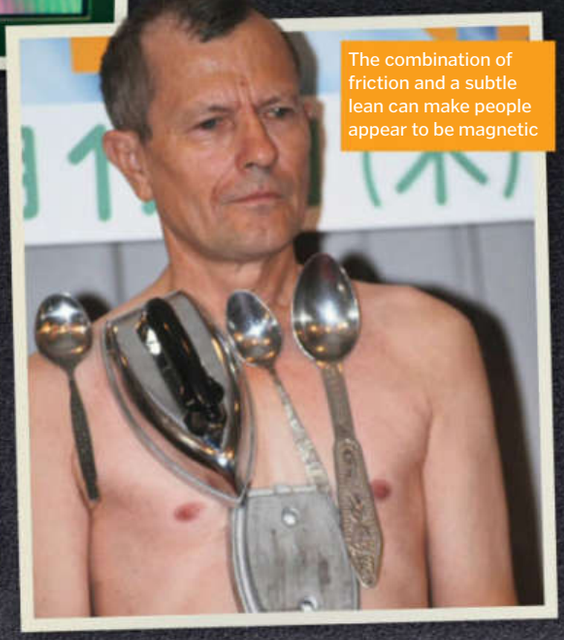
Cathode ray tube (CRT) television screens and computer monitors are very sensitive to the effects of magnets. This is because the image is produced by a stream of charged electrons. Inside the screen is a cathode ray tube – a vacuum tube containing a heated filament that produces a steady supply of electrons. These hurtle towards the screen, where they collide with chemicals known as phosphors, changing their colour. Holding a magnet to the screen bends the path of the electrons, warping the image.



Distortion on CRT screens can be removed by 'degaussing' – using a magnetic field to return the screen to normal

Can people be magnetic?

Some people are able to stick metal objects to their bodies in positions that appear to defy gravity, but despite appearances, there is no evidence that they are magnetic. Their apparently supernatural abilities are actually down to friction – objects cling surprisingly well to hairless, clammy skin.



The combination of friction and a subtle lean can make people appear to be magnetic

Magnetic sand contains magnetite, a magnetic compound made from iron and oxygen

What is magnetic sand?

Magnetic sand, also known as black sand, is made from tiny grains of the iron oxide, magnetite. It is much heavier than normal silicone-based sand, so patches of magnetic sand can sometimes be found where other grains have been swept away by the wind.

What happens when you divide a magnet?

Inside a magnet, all of the magnetic domains are neatly aligned, with their north poles all pointing in one direction. If you cut it carefully, you end up with two new magnets, but vibrate it too much and the domains will be knocked out of line.

If you were careful, you could carry on cutting to make thinner and thinner magnets

The spikes in this liquid are caused by tiny particles of magnetic material

Are any liquids magnetic?

Yes, ferrofluids are liquids containing tiny suspended particles of magnetic materials – usually cobalt or iron. The particles are kept separate using chemicals known as surfactants (similar to washing up liquid). If you put a magnet close to some ferrofluids, it will pull the liquid into spikes along the field lines.

WHAT WOULD THE WORLD BE LIKE WITHOUT MAGNETS?

If we hadn't worked out how to use them, everything would be very different

No navigation

In uncharted landscapes, explorers rely on compasses to find their way, using a floating magnetic needle to point to Earth's magnetic north pole. It is thought that the first practical compass was made in 1274, providing an invaluable tool for navigating the seas and oceans, and eventually leading European explorers to the Americas.

No data storage

From cassette and video tapes, to floppy disks and hard disks, many of our early methods of digital data storage relied on magnetic tape. To store the information, a current is passed through a coil of wire, creating a magnetic field that changes the direction of the magnetic domains of tiny metal particles embedded in the tape.

No radar (or microwaves)

The radio waves used in radar, and the microwaves used to cook your dinner, are produced by a piece of equipment called a magnetron. A powerful magnet is used to curve the paths of electrons as they move through a tube. They fly past specially designed cavities, causing them to resonate and producing electromagnetic radiation.

No electricity

We knew about electricity before the 1800s and had even created chemical batteries, but electrical generators relied on magnetism. The invention of the dynamo in the 1800s paved the way for the invention of the light bulb, and then all of the other electrical gadgets that we use today followed. Even now most of our electricity is generated using magnets.

No fridge magnets

It might seem like a small loss, but these humble magnets defy gravity as they cling to the door of your fridge. Sold as souvenirs across the world, fridge magnets are an everyday reminder of the strength of the electromagnetic force.

No music

Well, only live acoustic music. Speakers rely on magnets to produce sound. An electrical signal is passed through an iron coil attached to a fabric or metal diaphragm, turning it into an electromagnet. This is either attracted to, or repelled by, a nearby permanent magnet, making the diaphragm vibrate and reproducing the sound.

A RECORD-BREAKING MAGNETIC FIELD

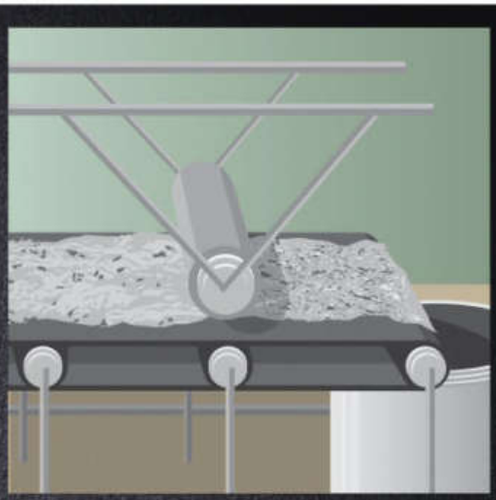
More than 1,400 scientists a year from around the world do research at the MagLab

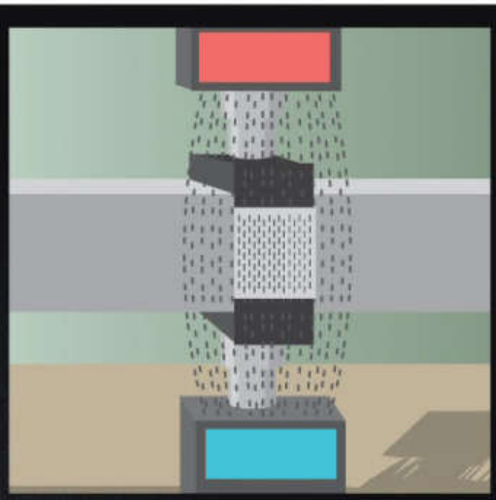
The Los Alamos National Laboratory in New Mexico is home to a record-breaking electromagnet. Inside the Pulsed Field Facility is a £6.3-million ($10-million) electromagnet, capable of generating a field strength of up to 100 tesla (20,000 times stronger than the average fridge magnet). An electromagnet this powerful requires huge amounts of energy; this causes rapid heating, limiting the amount of time that the magnet can be used for.

Most other magnets capable of achieving this kind of magnetic field are not able to withstand the strain, and break dramatically at the end of a single use. The magnet at the Pulsed Field Facility can be used over and over again. Each session lasts for just 15 milliseconds, but that gives scientists just enough time to perform their measurements. The magnet sits inside a tank of liquid nitrogen at -198.15 degrees Celsius (-324.67 degrees Fahrenheit), helping to limit the amount that it heats up during the burst. It is then renewed and ready for another go within an hour.

How to make a neodymium magnet

Manufacturing powerful magnets requires some specialist equipment





1 Combine the raw ingredients

Neodymium magnets are made from three key ingredients – neodymium, iron and boron. The finely powdered metals are mixed and melted together in a vacuum induction furnace.

2 Grind them into powder

The molten mixture is then poured into moulds or strips. These are allowed to cool before being broken into chunks. The chunks are then ground into a fine powder, each grain hundreds of times smaller than a full stop.

3 Align the magnetic fields

Moments before the metal powder is pressed into the final shape of the magnet, a magnetic field lines up the magnetic moments of the particles inside. The machine squashes the powder, locking them into position.

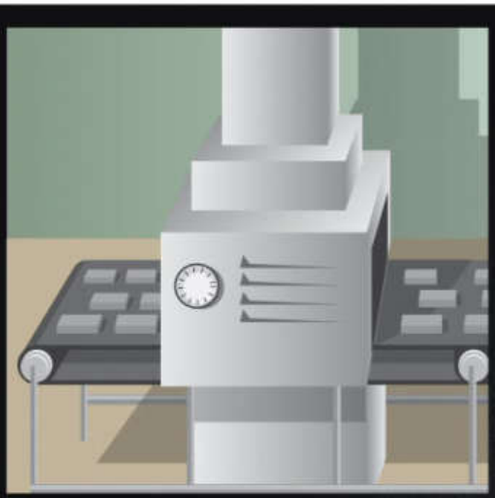
The 100 Tesla Pulsed Magnet is powered by a huge 1.4-gigawatt generator

Permanent magnets vs electromagnets

There are two main groups of magnets, each with different properties and uses. Permanent magnets, like the ones that you might stick to your fridge, have a fixed and constant magnetic field. Electromagnets, used in headphone speakers, for example, are only magnetic when a current is passing through them.

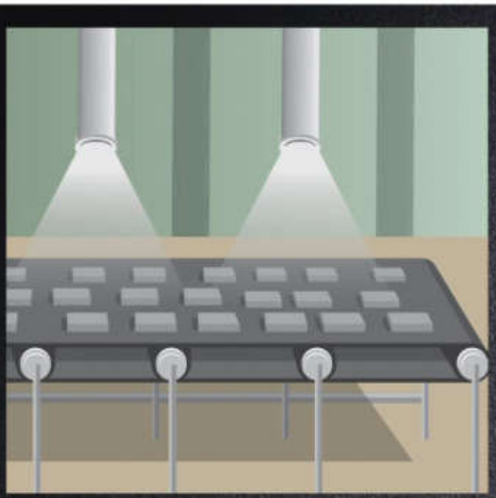
VS

PERMANENT		ELECTRO
Permanent magnets are always magnetic, unless they are dropped or damaged.	**ON OR OFF**	Electromagnets can be easily turned on and off at just the flick of a switch.
The strongest permanent magnets are made using neodymium. Once made, their strength is fixed.	**STRENGTH**	The strength of electromagnets can be varied by changing the number of wire coils or varying the current.
Permanent magnets are made from 'hard' magnetic materials, capable of holding their orderly magnetism.	**MATERIAL**	Electromagnets are made from 'soft' magnetic materials, which only line up when a current is applied.
Permanent magnets have no moving parts, and are very cheap and simple to use.	**SIMPLICITY**	Electromagnets are more complex and costly, and they generate heat when used.
Permanent magnets can be damaged by knocks, chips and other magnetic fields.	**FRAGILITY**	Electromagnets do not work without electricity, and can overheat if not properly cooled.



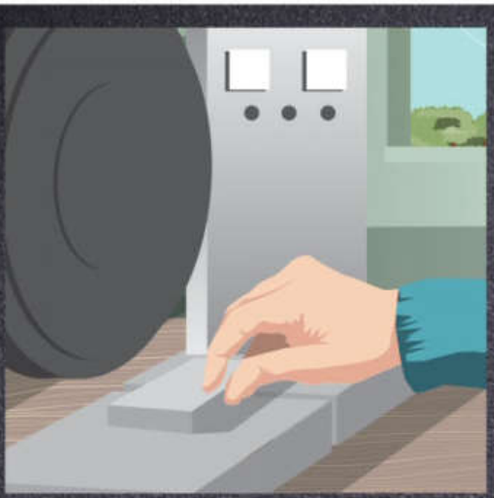
4 Bind the magnet together

The compressed bar of powder is transferred into an oven for a process known as sintering. First a low heat evaporates any water, and then a higher temperature melts the metal enough to stick the powder together.



5 Add a protective coating

The iron in neodymium magnets makes them susceptible to rust, so before being used they are given a protective coating. Different coverings are used depending on the purpose of the magnet.



6 'Charge' the magnet

At the end of the process, the magnetic moments inside the magnet are lined up, but they do not produce a strong external magnetic field. This is achieved by using an electromagnet to deliver a magnetising pulse.

COSMIC MAGNETISM

Magnetic fields in space are responsible for awe-inspiring and sometimes dangerous events

Magnetism is responsible for space weather, including the coronal mass ejections that can interrupt GPS, telecommunications and power grids. It is also the force behind the stunning spectacles of both the northern and southern lights.

Almost all of the plasma in the universe (as far as we know) is magnetised. As charged particles whip past one another, they generate currents, which in turn create magnetic fields. This happens inside stars, in cosmic dust clouds and in pulsars dotted around the spiral arms of the Milky Way galaxy. Fluctuations in magnetic fields can fling charged particles into space, and when they collide with another magnetic field, the resulting interactions can have very powerful effects.

Earth has its own internal dynamo which turns the planet into an enormous bar magnet, and in early 2015 NASA launched four identical spacecraft as part of their Magnetospheric Multiscale Mission. Orbiting in a pyramid formation, they are gathering information about a phenomenon known as 'magnetic reconnection', where the two fields temporarily link up, transferring energy from one to the other.

Auroras

The Sun releases streams of charged particles into space as solar wind, and when these collide with Earth's magnetic field, they squash and distort it – the side facing the Sun becomes flattened, and the far side stretches out. This enables some particles to interact with the magnetic field lines, generating currents of electrons that travel toward the poles. The electrons collide with gasses in the atmosphere, which gain energy and then release it as light.

The magnetosphere

Earth's magnetic field protects us from powerful and damaging solar winds

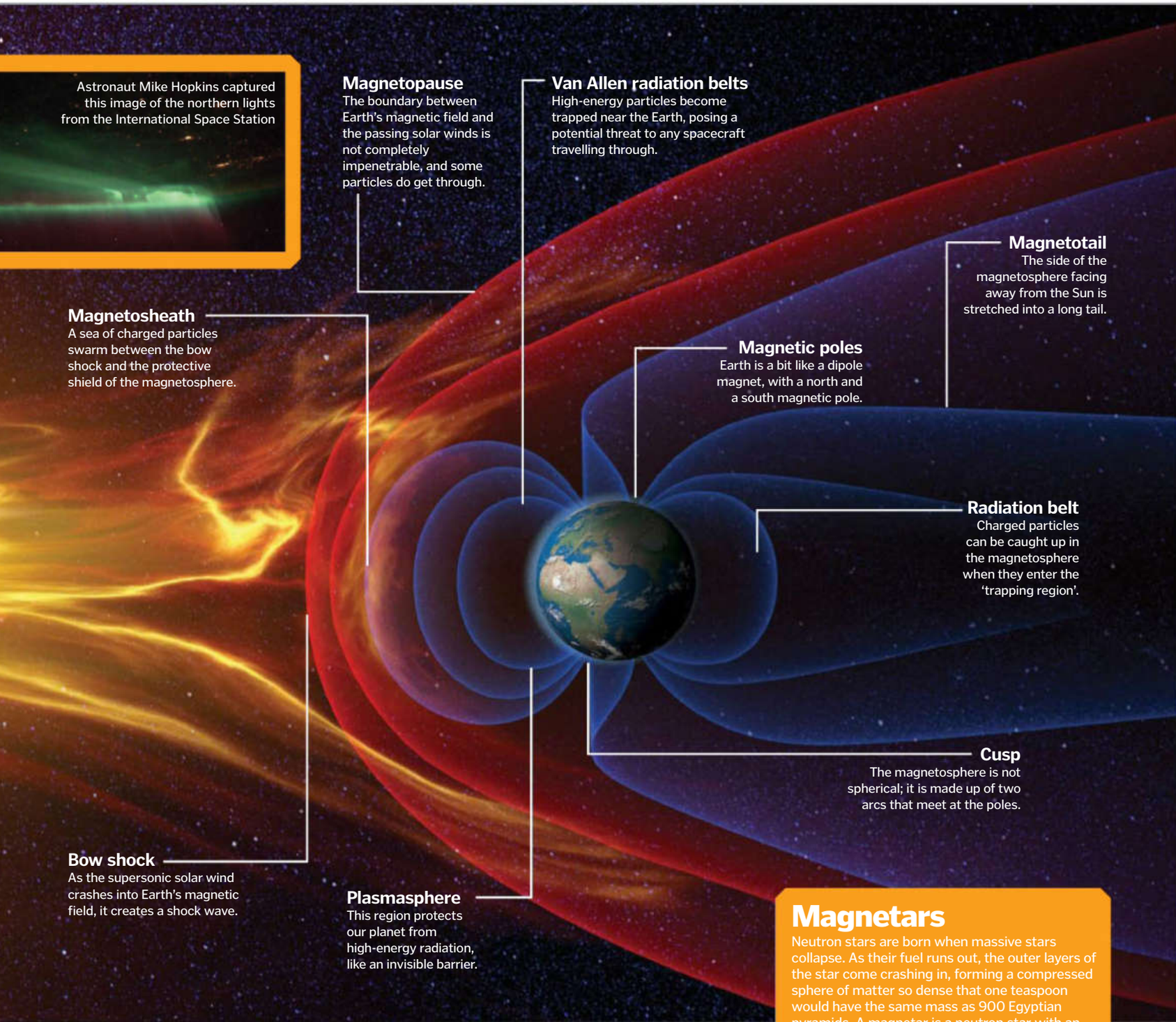
Solar wind
The Sun constantly releases streams of charged particles out into space.

This image, captured by NASA's Solar Dynamics Observatory, shows loops and magnetic fields of a sunspot

The Sun's magnetic field

The Sun is made of plasma – a state of matter different from a solid, liquid or a gas. It is a sea of positive and negative particles, and as the particles move, they generate electrical currents, which creates magnetic fields.

The fusion reactions that power the Sun keep the plasma moving and as it spins on its axis, the charge particles are whipped up even more. Solar winds blowing away from the Sun's surface also contribute to the changing magnetic fields, and occasionally pockets of extremely strong magnetism build up. This drives hot plasma away from the surface in arcs, forming sunspots or coronal mass ejections.



Astronaut Mike Hopkins captured this image of the northern lights from the International Space Station

Magnetopause
The boundary between Earth's magnetic field and the passing solar winds is not completely impenetrable, and some particles do get through.

Van Allen radiation belts
High-energy particles become trapped near the Earth, posing a potential threat to any spacecraft travelling through.

Magnetotail
The side of the magnetosphere facing away from the Sun is stretched into a long tail.

Magnetosheath
A sea of charged particles swarm between the bow shock and the protective shield of the magnetosphere.

Magnetic poles
Earth is a bit like a dipole magnet, with a north and a south magnetic pole.

Radiation belt
Charged particles can be caught up in the magnetosphere when they enter the 'trapping region'.

Cusp
The magnetosphere is not spherical; it is made up of two arcs that meet at the poles.

Bow shock
As the supersonic solar wind crashes into Earth's magnetic field, it creates a shock wave.

Plasmasphere
This region protects our planet from high-energy radiation, like an invisible barrier.

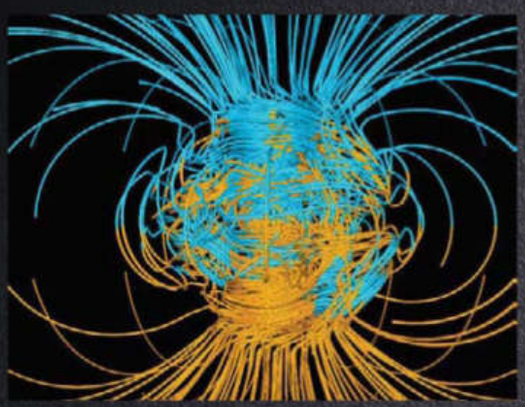
Magnetars

Neutron stars are born when massive stars collapse. As their fuel runs out, the outer layers of the star come crashing in, forming a compressed sphere of matter so dense that one teaspoon would have the same mass as 900 Egyptian pyramids. A magnetar is a neutron star with an extreme magnetic field. Not every neutron star is a magnetar, however. It is thought that in order to generate such an intense magnetic field, the collapsing star must be rotating very rapidly.

Magnetars, or 'magnetic stars', can have magnetic fields that are trillions of times stronger than Earth's

Earth's internal dynamo

The Earth's inner core is a solid ball of iron and nickel, spinning at its own pace at the centre of the planet. It is surrounded by a hot, molten iron-nickel layer, and as it turns, it whips the liquid into whirlpools. Residual heat, from the formation of our planet and the movement of the Earth as it turns on its axis, keep this sea of electrically conducting ions in constant motion, generating a magnetic field.



The complex movements of the liquid outer core change the pattern of Earth's magnetic field over time

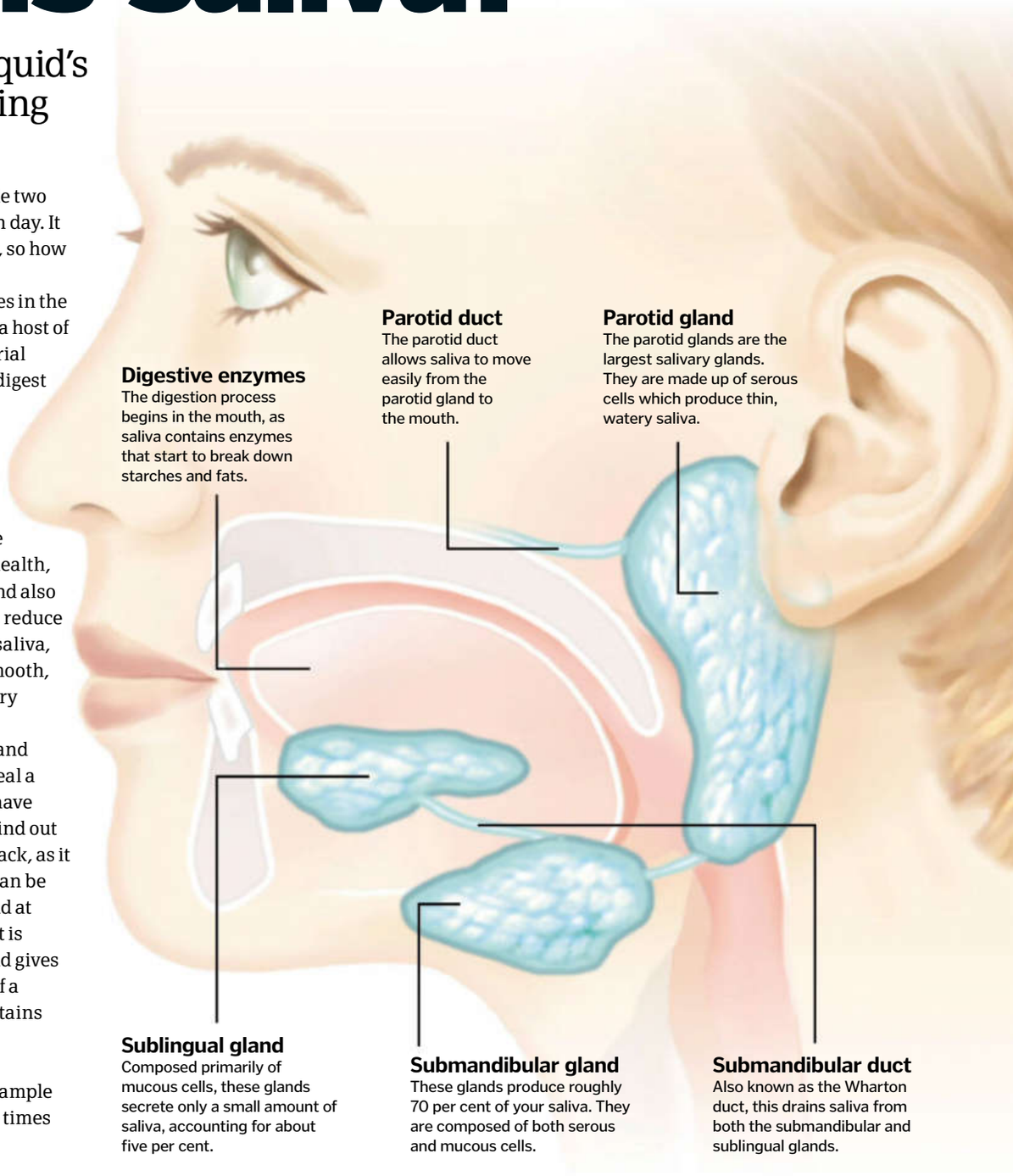
What is saliva?

Find out this frothy liquid's vital role in maintaining human health

Humans can produce an incredible two litres (half a gallon) of saliva each day. It is made up of 99.5 per cent water, so how is it able to perform so many important functions in our mouths? The answer lies in the remaining 0.5 per cent, which contains a host of enzymes, proteins, minerals and bacterial compounds. These ingredients help to digest food and maintain oral hygiene.

As soon as food enters the mouth, saliva's enzymes start to break it down into its simpler components, while also providing lubrication to enable even the driest snack to slide easily down the throat. Saliva is also important in oral health, as it helps to protect teeth from decay and also controls bacterial levels in the mouth to reduce the risk of infection. Without sufficient saliva, tongue and lip movements are not as smooth, which, in extreme cases, can make it very difficult to speak.

With advanced scientific techniques and research, an individual's saliva can reveal a great deal of information. New studies have shown that a saliva test can be used to find out whether a person is at risk of a heart attack, as it contains C-reactive protein (CRP). This can be an indicator of heart disease when found at elevated levels in the blood. A saliva test is much less intrusive than a blood test and gives doctors a rough estimate of the health of a patient's heart. What's more, saliva contains your entire genetic blueprint. Even tiny amounts, equivalent to less than half a teardrop, can provide a workable DNA sample that can be frozen and thawed multiple times without breaking down.



Digestive enzymes
The digestion process begins in the mouth, as saliva contains enzymes that start to break down starches and fats.

Parotid duct
The parotid duct allows saliva to move easily from the parotid gland to the mouth.

Parotid gland
The parotid glands are the largest salivary glands. They are made up of serous cells which produce thin, watery saliva.

Sublingual gland
Composed primarily of mucous cells, these glands secrete only a small amount of saliva, accounting for about five per cent.

Submandibular gland
These glands produce roughly 70 per cent of your saliva. They are composed of both serous and mucous cells.

Submandibular duct
Also known as the Wharton duct, this drains saliva from both the submandibular and sublingual glands.

Saliva performs a variety of functions and can actually help wounds to heal

Can saliva speed up healing?

Many animals do it instinctively, but it turns out that there is a benefit to humans licking their wounds. A study found that there is a compound in human saliva, namely histatin, which can speed up the healing process. Scientists conducted an experiment using epithelial cells from a volunteer's inner cheek, creating a wound in the cells so that the healing process could be monitored.

They created two dishes of cells, one that was treated with saliva and one that was left open. The scientists were astounded when after 16 hours the saliva-treated wound was almost completely closed, yet the untreated wound was still open. This demonstrated that saliva does aid the healing of at least oral wounds, something that has been suspected but unproven until this study.

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Why do crackers have holes in? And ten other tasty questions about food

Why does popcorn pop?

Popcorn kernels contain starch and a small amount of water. When cooked, the water inside expands as it evaporates into steam, and turns the starch into a gooey paste. The hard shell manages to contain it until the pressure gets too high and it ruptures with a pop, which is typically at a temperature of 180 degrees Celsius (356 degrees Fahrenheit). The drop in pressure and escaping steam causes the starch to expand and solidify as it cools, forming puffy white flakes.

Why do avocados go brown quickly?

When an avocado is cut open and its flesh is exposed to oxygen, the enzyme polyphenol oxidase converts chemical compounds called phenols into quinones. These quinones produce polymers called polyphenols, which turn the flesh a brown colour. Of course, most fruits turn brown eventually, but the process occurs more quickly in avocados because they contain more polyphenol oxidase. To slow this down, wrap it in clingfilm to limit oxygen exposure, or add acidic lemon juice which can slow down the enzymes.

Why is milk white?

Milk is about 87 per cent water, with the remaining 13 per cent consisting of fat, proteins, lactose, vitamins and minerals. The fats and proteins in milk are what give it its white colour. These molecules reflect all visible wavelengths of light, which, when combined, are perceived by our eyes as white. Without the fats, the smaller protein molecules in milk reflect more blue wavelengths of light, which is why skimmed milk can have a slight blue tinge.

Do carrots improve your vision?

The myth that carrots help with night vision was actually started by the Royal Air Force during World War II. To keep their new radar system a secret, they claimed that eating lots of carrots was helping their pilots spot enemy planes. Although this wasn't true, carrots can help promote healthy eyesight. They contain a chemical compound called beta-carotene, which your body converts into vitamin A and then retinal. Retinal is found in your eyes and helps to convert light into a signal that can be transmitted to the brain, but this won't actually help to improve your vision.

Why does bacon smell good?

The aroma of sizzling bacon is the result of around 150 different compounds. As the bacon is cooked, sugars react with amino acids in what is known as the Maillard reaction – the same process that causes it to turn brown. The Maillard reaction, combined with the melting fats, is what produces the aroma compounds. Around two-thirds are hydrocarbons and aldehydes, but the main contributors to that meaty smell are actually the nitrogen-containing compounds pyridines and pyrazines.

Are frozen vegetables less nutritious?

When vegetables are frozen, they have usually just been picked and are therefore at the peak of their ripeness and nutritional value. Before freezing, they undergo a process called blanching, where they are dunked into boiling water and quickly cooled. This process helps to deactivate the enzymes that would otherwise reduce the vegetables' nutritional value. Therefore, frozen vegetables may actually be more nutritious than the fresh produce that has surpassed its peak ripeness on its way to the supermarket.

Why does pepper make you sneeze?

Sneezing is a reflex your body uses to remove irritants from inside your nose, and one particularly effective irritant can be found in pepper. Black, white and green pepper contain an alkaloid called piperine, the chemical that gives it that spicy flavour. When piperine gets into your nose, it acts as an irritant by stimulating the nerve endings inside the mucus membrane. To get rid of it quickly, your body's involuntary reflexes will cause you to sneeze.

Why does asparagus make your wee smell?

Asparagus is unique as it contains the chemical asparagusic acid. When digested, this produces sulphur compounds such as methanethiol and dimethyl sulphide that, when excreted in urine, give it a distinctive smell. However, this only affects around 40 per cent of humans. Thanks to a genetic mutation, most people are unable to excrete the compounds that produce the smell, while others are unable to smell the compounds due to another genetic mutation that has switched off a particular smell receptor.

Why does garlic make your breath smell?

When garlic is chopped or crushed, enzymes convert the chemical compound alliin into allicin, which is then broken down into a four further compounds. It's these four compounds that are responsible for garlic breath. Allyl methyl sulphide is the main contributor, as it takes longer for your body to break it down, leaving it to pass into your bloodstream and be excreted in your sweat, breath and urine.

Why do crackers have holes in?

The holes in crackers aren't there for decoration; they actually ensure the tasty treats bake properly. The cracker dough contains lots of trapped air bubbles, and when it is heated in the oven, these pockets of air expand. To stop these bubbles from expanding and bursting, a machine called a docker pricks holes in the dough to allow the air to escape. This keeps the crackers flat and crispy, with minimal air bubbles.

Why doesn't honey go off?

Honey is one of the very few foods that doesn't spoil over time. This is down to several factors, the first being its very low water content which dehydrates bacteria, making it unable to grow. On top of this, honey is very acidic, because when bees regurgitate nectar to produce it, enzymes in their stomach break it down into gluconic acid and hydrogen peroxide. These chemicals also create a hostile environment for bacteria, killing it off before it can spoil the honey.

Laser hair removal

Does this technique really banish unwanted hair for good?

Laser hair removal isn't cheap; a single treatment of a large area can cost in the region of £640 ($1,000)

Laser hair removal works by firing a specific concentrated light beam at the undesired hair, with a wavelength that targets melanin – responsible for hair colour – and the hair bulb – where living cells divide to build the hair shaft. The laser uses your hair to absorb heat, which causes inflammation to form around the follicle, effectively killing it. As the hairs are not targeted individually, the process is much quicker to carry out than electrolysis, but may cause damage to the skin if it is not carried out correctly.

If you are relatively pale with dark hair this treatment should work very well, however, its limitations lie with people that do not have contrasting hair and skin colours. This means that less of the laser beam is absorbed into the hair, making the treatment much less effective. Even when this technique works it is rarely permanent; patients need between one and four treatments a year to maintain it. This is because at any one time, a number of your hairs will be in the resting phase of growth, meaning that they won't be affected by the laser treatment and will grow back again.

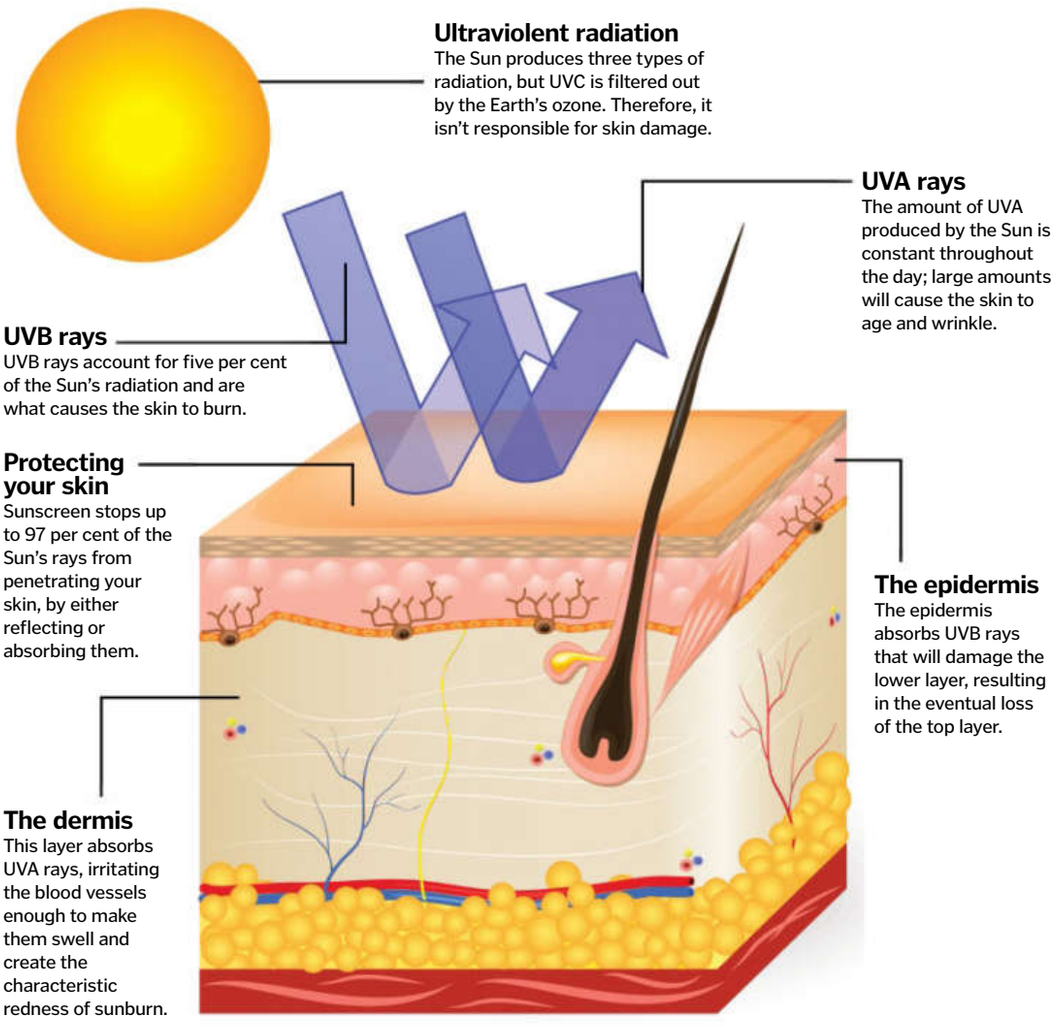
How does sunscreen work?

See how this clever substance protects our skin from harmful UV rays

The dangers of the Sun's rays have long been appreciated by humanity. The ancient Greeks slathered themselves with olive oil, while ancient Egyptians used extracts of rice and jasmine that are still present in modern day skincare products.

Whether it is in the form of a spray, lotion, gel or wax, modern sunscreen works by combining ingredients that either block or absorb the Sun's dangerous ultraviolet (UV) rays. Minerals such as zinc oxide reflect UV rays directly, whereas organic chemicals such as avobenzone absorb UV radiation into their chemical bonds, and then gradually release it as heat. The Sun Protection Factor, or SPF, indicates how well the sunscreen will block the Sun's UVB rays, which are responsible for burning the skin. An SPF 15 sunscreen will prevent your skin from burning for 15 times longer than it usually takes for you to burn, but will only block out around 93 per cent of UVB rays.

The chore of rubbing on sunscreen may soon be a thing of the past, however. There is currently a race to develop a pill that will provide full UV protection, based on a compound produced by the algae that live inside coral. Scientists hope to see this product for sale on the market in the coming years.



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HOW VIDEOGAMES ARE MADE

Discover the incredible journey from concept to console

Playing a videogame is like entering a whole new world full of sights, sounds, artificial intelligence, simulated gravity and unique environments. The traditional videogames, such as *Mario* and *Space Invaders*, relied on consoles or arcade machines to work, but nowadays gaming is everywhere: on your phone, on your tablet, even in your TV.

It takes a variety of different skills on the journey between someone's first thought for a game and that same idea appearing in your hands. Some development studios employ hundreds of people, while other games are made with teams of only ten or less. It's not just a matter of knowing about the programming languages videogames are constructed with, development teams also have to learn about 3D modelling or pixel art to make the product look like a game, and they have to master audio design and sound-mapping to make the product sound like a game too.

The first thing a studio needs when making a new game is a plan that includes a plot, a cast of core characters and some sort of interactive action. These three elements are typically mapped out and combined during the 'pre-production' period – storyboards, concept art and vertical slices (a finished portion of a game) are designed here. These early tests are compiled into a game design document – a visual guide that details everything; from how menus work and character backstories, to how far a character can jump and level design.

Once a game design document has been created, the more technical side of development begins. This is a more interactive step in the game-making process, where programmers and coders will decide upon the engine they'll be using to build the game, and start to create playable situations where the team can test certain 'states' of their build. Big-budget games require a huge selection of programming tasks to be undertaken at this stage, including the simulation of in-game physics, the scripting of the AI and the generation of menu elements (or the user interface).

Programming is typically undertaken in the game's codebase – think of it as a library of information the game can constantly pull material from. A codebase is a script unique to each game, and isn't dissimilar from a huge computer summoning documents from files stored on its drive. If a game knows it needs to show three enemies and an explosive barrel on screen, the codebase will be organised so the game's script can easily and quickly find those assets and load them.

BRINGING THE GAME TO LIFE

Without the skills of the programming team, you wouldn't be able to get past a game's title screen

Physics programmer
Everything you touch in a game has a real-world weight, resistance and shape to it. It's down to the physics programmer to make sure that all in-game 'gravity' works as it needs to, so that it's not too heavy or too light.

AI programmer
Enemies in games would be boring if they always acted the same way. So it's the AI programmer's job to create scripts that inform how they react once they spot you, as well as where to patrol and how often they need rest.

Audio engineer
Just because the audio team has made the sounds for the game, that doesn't mean they'll trigger when they need to. The audio engineer maps out the sounds to places in the world, including voice acting and even music.

Input programmer
Are you playing on an iPad or a PlayStation, and with touch controls or a joypad? The input programmer determines this and ensures all player commands are 'listened to' by the game.

Level designer
Every obstacle, every enemy and every wall to climb over, has been intentionally thought about to challenge the player and make them learn more about the game's mechanics. That's the level designer's job.

Systems designer
A game like *Pokémon* works by running a highly advanced set of algebraic formulas off against each other. It's the systems designer that ensures the maths behind these formulae is perfect and bug-free.

Network programmer
If a game has any online functions or can be played in multiplayer mode, a network programmer needs to oversee production on how your game will communicate with other players' games, and how the code will cope with 32 players at once.

Narrative designer
The narrative designer works with the writer to make sure open-ended games still make sense when played 'out of order'. Most games have over 30,000 lines of dialogue these days, so this role is a mixture of word and maths-based programming.

Most modern titles run on game engines which can interpret and 'translate' script. Amazingly, many of these are available for free to anyone interested in learning how to use them. These engines – Unreal, Unity, CryEngine, UbiArt – can simulate physics, graphics and sound at the press of a button, meaning developers and programmers can test out their codes much faster with an engine than without one. Studios may have specific roles for people that know how to use an engine, or a programmer might be able to perform both tasks on the same project.

By now, the main game 'mechanics' will be in place. Think of these in terms of gameplay – Mario's jump, *Sonic the Hedgehog*'s spin-dash, *MineCraft*'s building; these are all classed as mechanics. It's at this point that the graphics team steps in. If the studio has decided their character will be a human (or even just humanoid), a motion capture (or MoCap) team can begin work on recording and implementing real-world movements by mapping them onto an in-game character. If the characters are monsters, dragons or something else entirely, the animators and 3D artists will get to work on putting these together. There are many different programs capable of creating 3D art, so it's important to ensure the 3D engine will 'speak' to the game engine – a game wouldn't work if none of the characters' costumes loaded onto their bodies; you'd just see the 3D skeleton of a stickman walking around! Lastly, a sound design team must ensure all the sound-effects – from gunshots to bridges creaking – are in place. This can be done by recreating them within the game's engine, or recording them and applying them to the in-game world.

There can be hundreds of people working in any one game studio, but that doesn't mean smaller groups of people can't design their own game. It's possible for a single person to release a game on their own too, if they can learn the very specific skills required to produce an interactive story! Over the next few pages, you'll learn exactly how a game goes from a concept to your console.

The 250-strong team at EA studio Visceral Games are responsible for the likes of *Battlefield: Hardline* and the *Dead Space* franchise

THE TEAM BEHIND A VIDEOGAME

Designer
A designer can be seen as the studio 'head', like a film director. It'll be their vision and their ideas that the game is based on.

Programmer
The person responsible for making sure the game does what you tell it to do, the programmer writes scripts for in-game 'mechanics'.

Artist
All the original visuals stem from the artists; they will provide the concept sketches, landscapes, character clothing and details.

3D artist
The member of the team responsible for re-creating the artist's work in 3D; producing textures, working on weapons and armour and even making terrain.

Animator
The animator will make the 3D artist's characters come to life, either through manually creating scripts that make figures move, or by applying motion capture data.

Producer
A jack-of-all-trades that makes sure the development deadlines are on track. They also acquire funding or other necessary assets for the development studio.

Writer
The author of the game. Writer's jobs can vary from providing a key narrative arc for the game to giving in-game characters scripts or backstories.

Audio programmer
Creating the sound is usually undertaken by a team of recorders and foley artists (who reproduce everyday sound effects).

Game Tester
Referred to as 'bug hunters', the quality and assurance team find parts of the game that don't work properly and log them for programmers to fix.

Game production milestones

A development studio must complete many 'milestones' in order to get their game into your hands

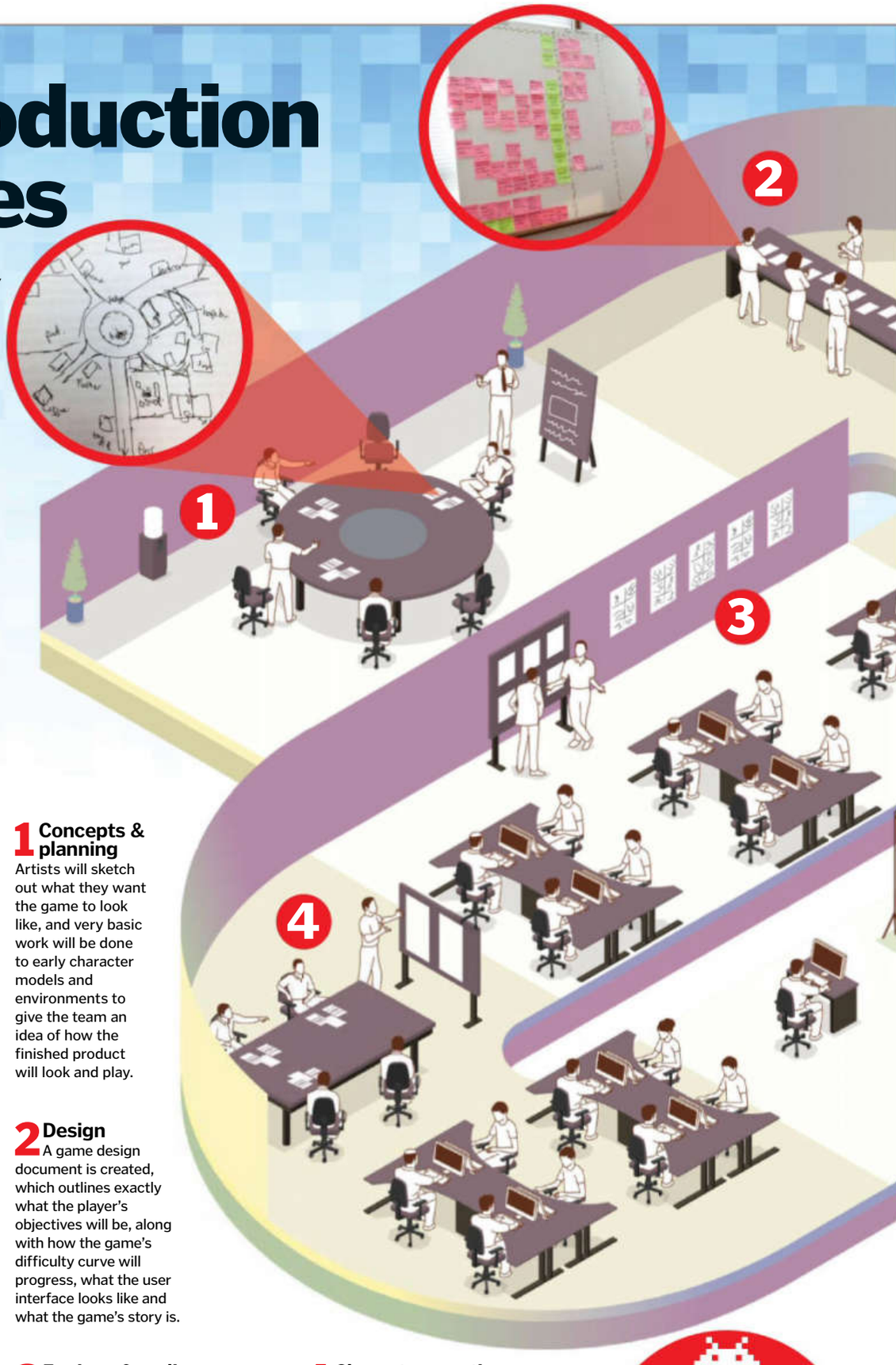
Videogame development is hard to track; after all, there are so many different parts of the game that are being worked on simultaneously, that it's difficult to measure how close to completion a game actually is. As such, development studios use 'milestones' to gauge their progress and mark major achievements in their projects. There is no industry standard when it comes to milestones, but a typical game – which takes roughly two years to make – would follow a pattern similar to this.

The first playable: The first playable state is exactly what it sounds like – the very first draft of a game that contains gameplay and assets representative of the final product. This build will be very closely based on what's outlined in the game design document, and is typically ready 12 to 18 months before a game's release.

Alpha: The alpha stage of development is when all of the key gameplay elements have been implemented. Ideally, a game in alpha should be 'feature complete', which means the product contains all the ideas and controls that will be used in the final build. The codebase should be roughly 80 per cent complete at this point, and programmers will focus on finishing this before adding extra content or features.

Beta: A game in its beta phase is practically complete. The design team has signed off the product as 'code freeze', a term implying that no more code may be added to the game, and only bugs or glitches may be addressed. A beta build will contain near-complete graphics and might only lack some precise details, such as the way some in-game items behave with the environment, for example.

Going gold: Once a game 'goes gold', it's officially out of the studio's hands. The final build of the game is signed off and sent to be printed onto Blu-ray discs, cartridges or computer chips (for arcades), and a digital copy is sent to publishers who'll host the title on their online stores once release day hits.



1 Concepts & planning
Artists will sketch out what they want the game to look like, and very basic work will be done to early character models and environments to give the team an idea of how the finished product will look and play.

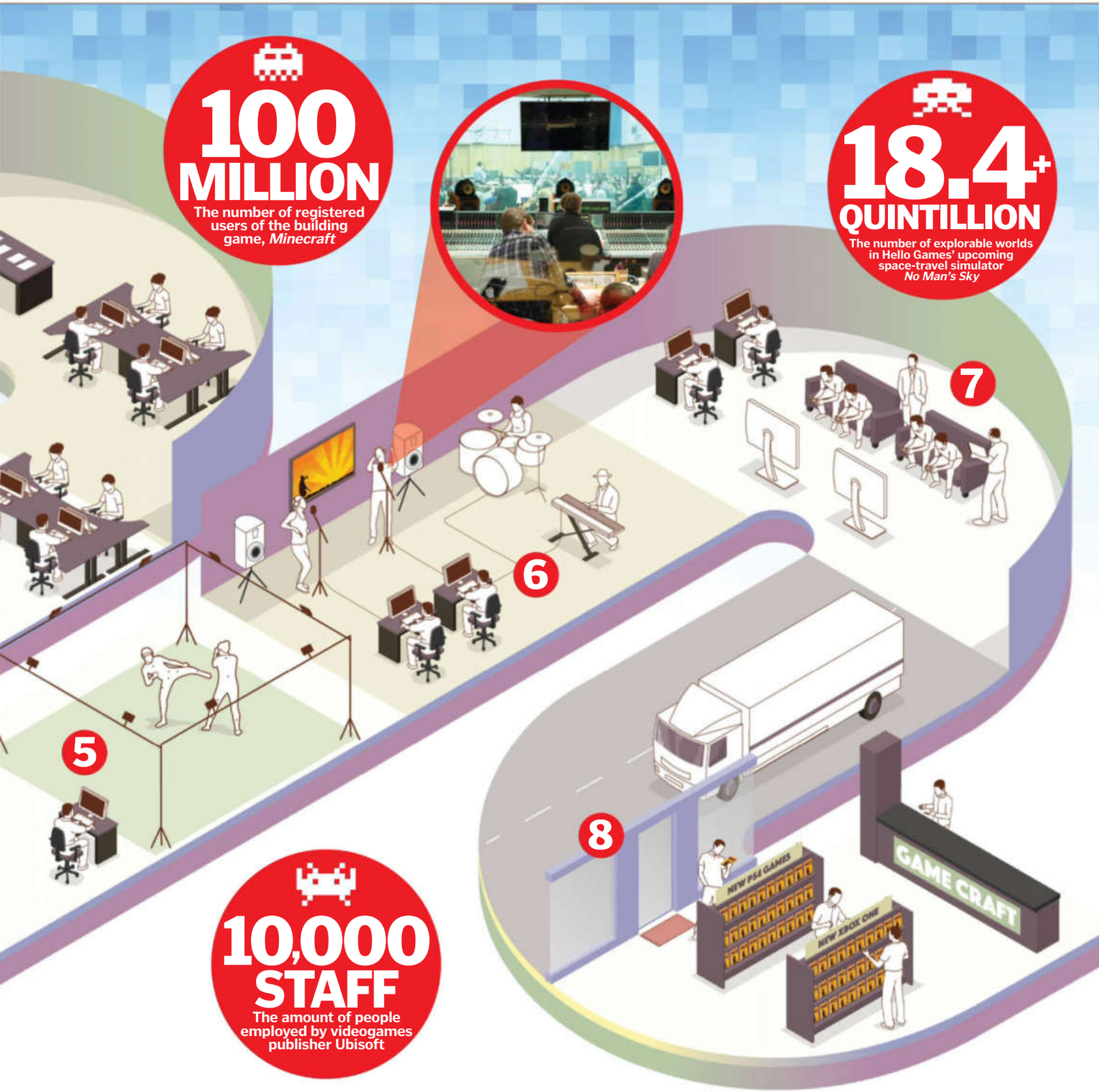
2 Design
A game design document is created, which outlines exactly what the player's objectives will be, along with how the game's difficulty curve will progress, what the user interface looks like and what the game's story is.

3 Engines & coding
An engine is chosen for the game and this will determine the software tools the programmers will work with as production continues. All the interactive elements of the game – from controller input to character movement and more – are designed and implemented here. Programming languages like C++, Python or BASIC are used to fine-tune details that the engine can't manage.

4 Character creation
In-engine tools and separate 3D art software are used to build characters from the ground up. Each individual part of the character is worked on first – the body, the hair, the face, the clothes – until eventually every bit of the model is put together. New software is in development all the time, allowing for more lifelike creations. For example, TressFX is a system built specifically to render realistic hair.

$265 MILLION
The amount of budget it took to make *Grand Theft Auto V*

DID YOU KNOW? *Nintendo, publisher of the Mario and Pokémon games, actually began life as a playing cards company in 1889!*



5 Motion capture

Once the character models are in place, actors resembling their physical shape are hired and kitted out in special suits that read their movements in a 3D grid. The actors perform actions – drawing a sword, rolling forward, dodging and so on – and all the data is extrapolated from the 3D grid and translated into in-engine sequences that programmers can apply to certain inputs or commands.

6 Sound design & scoring

A composer will receive an early (alpha) build of the game and play through it to get a feel for the atmosphere and tone, before creating a soundtrack based on this. Music design now tends to be dynamic, meaning composers must create their tracks so they can seamlessly transition, depending on where the player is moving or what actions they are performing. Sound effects are recorded by foley artists – who recreate various noises in a studio – and implemented here, too.

7 Debug & testing

Once all the characters, music, mechanics and graphics are in place, the game is released into its 'beta' phase. Here, teams of people systematically play through the game and log and errors or glitches in the code. These logs are compiled into reports and delivered to the core development studio at regular intervals, where the programmers dig into their old code to find, fix or replace bad lines of code that are causing the crashes or errors.

8 Pre-release

The game goes 'gold' (ready to be printed to disc) and a final build is packaged together and sent to manufacturers. Alternatively, the package is sent to a publisher (like Microsoft, Sony or Steam) and is hosted on that company's own digital storefront.

Illustration by Acute Graphics

Creating realistic characters

Having a lifelike cast of characters helps gamers believe in the world they are playing in

Videogame characters are reaching new heights of realism, to the point where it's normal to see pores in skin, minor cuts and bruises, and even flakes of snow settle on a costume. In the case of Lara Croft – in Crystal Dynamics' reboot of the *Tomb Raider* series – the team started by scanning an actress who shared the same proportions as Lara. Laser fields mapped out her body shape and size, and recorded every minute detail on her skin.

This data was then translated into 3D rendering software, where programmers could single out certain planes of the model and label them for quick access later. For example, a graphics programmer could select particular areas of the model, label it as 'skin', and apply a realistic texture to that selection to lay the foundation of the character model. The same process was then be repeated for every major part of the body before the programmers moved onto the face. If the character being created is fantastical, however, programmers take reference scans of something similar and use that as a base to work from. For example, a team in Germany – YAGER Development – were the first in the world to have motion-captured a cat!

3D faces used to be designed with 'bones' – reference points that could be manipulated to give the impression of facial expressions. A standard facial model ten years ago might have had 30 bones (the more bones, the smoother the animation). Nowadays, models are made with over 500 of these poseable points, which enable developers to animate faces to a more exaggerated (and readable) degree than what motion capture would pick up.

The final step is finding a voice actor for the role of the character. "I think that 99 per cent of a successful performance is in the casting and bringing people together," explains Troy Baker, the award-winning voice actor who has played many popular characters, including Joel in *The Last Of Us*. "We're starting to see an importance and a necessity in videogame storytelling for actors' performances to be of a high calibre." Voice actors can be recorded separately in studios, but this can lead to awkward dubbing where the tone of voice is disconnected with the character's actions on screen. Many studios now choose to have voice actors also providing the motion capture for their characters, so both the vocal and visual data can be recorded at the same time for a more realistic performance.

Lights
MoCap studios are typically very bright – the white nodes on the actors' suits need to be keyed onto all cameras at all times, so visibility is vital.

Sound
While some sound will be recorded in a specific studio, general effects, impact sounds and dialogue can be recorded on-set, for added realism.

Cameras
Depending on how many frames of data-per-second the animation team requires, more cameras will be installed in the studio.

Props
Guns, swords and other objects might also be fitted with special white nodes that will be tracked and recorded in the animation data.

Inside a motion capture studio

Once the characters are made to look real, the motion capture team brings them to life

Realistic faces

The 'bones' traditionally used in facial animation are slowly being overtaken by new technology. In *Rise Of The Tomb Raider*, for example, a new tool called MOVA is being used. MOVA is applied as a 'spraypaint' to the face, and provides around 7,000 points of reference. Cameras are then moved extremely close to an actor's face to pick up thousands and thousands of data frames per second. Think of it as green-screen that can be painted on, making it easier for cameras to pick up key reference points so the nuances of facial expressions can be mapped to the character.

The way meshes are created using real-world models improves year on year – getting us ever closer to the 'uncanny valley'

The rig
The rig keeps all the cameras and lights in place, ensuring that the action is well-lit and recorded from all angles.

Real-time visuals
Some studios have the facilities to directly interpret the animation data they're receiving into an in-game situation, so you can see a character walk around a game world in real-time!

Microphone
Certain studios (Ubisoft Toronto, for example) decide to film movement, voice and face all at the same time, and experiment with true-to-life 3D performances.

Studio director
Either the animation director or a studio head will oversee the session. They will make sure the actors are moving and responding in exactly the way the game design document outlined.

Recording
A series of computers hooked up to the cameras will interpolate the 3D data as it's recorded, transmitting it to 3D rendering software.

Actors
Actors wear special suits that are picked up by the cameras in the room and fed back to a computer, 'mapping' the animation in a 3D field.

Illustration by Nicholas Forder

Studio to screen

100 years ago, animators at Disney used live-action footage to 'trace' animations and then project them. That's fairly similar to how optical 3D motion capture works. Those white balls you see on MoCap suits are interpreted by software (like Autodesk's MotionBuilder) that project how the actor in the suit moves onto a skeleton character, which programmers can study in real-time. If the performance has unexpected results – which can happen due to the unpredictable nature of motion capture – a director will offer feedback to the actor that will directly affect the way data is produced on screen. This is a fairly modern practice, and is only a viable method of animating due to how quickly and efficiently modern computers can run.

Ninja Theory's *Hellblade* features the character Senua, whose MoCap was all achieved in a rig built by the developers themselves

Starting the engines

A game's engine is a software framework that interprets the code that videogames are made in, but there are many of them available for use.

Unreal

Unreal is a free-to-use engine that's been the most popular choice for developers in the last few years. It can deliver photorealistic graphics and lifelike lighting effects with minimal effort.

Unity

Modern independent developers have been using Unity due to its easily accessible interface and unique asset bank that enables you to use parts of games that other developers have made (if you pay for it!).

CryEngine

The most popular engine used to create photorealistic games; the CryEngine's drawback is that developers have to pay to use the engine. It's worth it when you see the final results, though!

Starling FrameWork

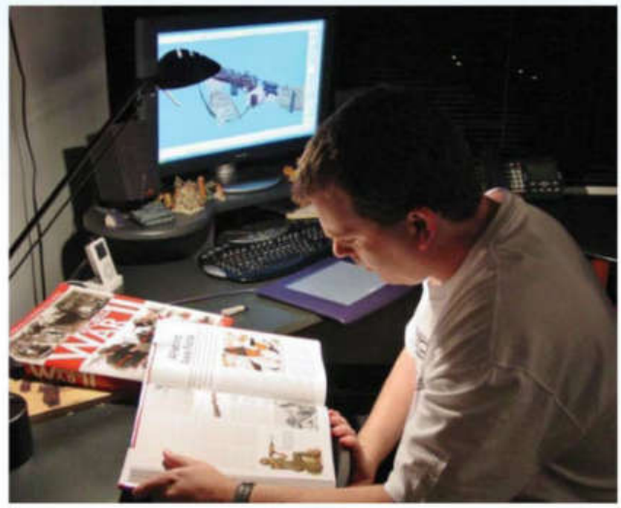
The *Angry Birds* mobile game was made in this engine, which is based on the standard internet browser platform, Flash. The engine specialises in fast-paced 2D games.

SDKs are hard to come by but are vital when testing out new games

Tools of the trade

Having a computer that's quick and powerful enough to run a game-making engine is one thing, but having a place to fully test an early build of your game is another important requirement. These test units are called SDKs (software development kits) and are usually given to studios via the console manufacturers (Microsoft, Sony, Nintendo). Having a kit in the studio means programmers can 'debug' their games in real-time – most test modes of games have a special button that lets developers break through the graphics and interface, and interact directly with the code that's running the game.

These kits used to be incredibly hard to get hold of – they basically let you 'look inside' a console's code and alter your game's cyber DNA to suit it – but nowadays they're becoming more and more common. In fact, Microsoft shipped out over 1,000 of these SDKs to independent publishers in the last two years alone!



Q&A with an audio designer

Lionhead Studios' Steve Brown explains what's involved in creating sound for videogames

What is the most difficult part of your job when implementing new sounds into videogames?

Game audio needs to be strict – just because you've got 300 megabytes of memory to play around with, you still need to maintain good file management. You're easily going to accumulate 100,000 WAV files, so without a filing structure and proper editing, the right sounds will never trigger on the right animations, and it's a nightmare. It results in a product that never syncs up.

Has the way game audio works changed a lot since you began working in the industry?

In terms of audio production, big budget games get to spend a lot of money on foley, but you can get so wrapped up in it. You've always got to question: 'Does this sound give key gameplay feedback to the player?' If the answer's no, you scrap it.

That's actually how we work in feature films, too – even if we've got the budget to put every single sound that could possibly be there in the film, we realise that isn't what we want to do. It can end up detracting from the things we actually want the audience to listen to.

What is the most important thing that you've learned from being hands-on in your job?

The biggest thing I've learnt from film and foley is the confidence to just try things out. As an audio designer, I can sit there with a library of pre-recorded stuff or a commercially available library, and I can sit for hours just trying to edit out tiny little elements: cloth movement, for example. You could try and cut that, but a single run could take hours.

How do you go about recording sound effects for things like magic or fantasy-based things in games?

[One of our games, *Fable Legends*] has an ice character called Winter. For her, we had to get the sound of cracking ice, but that's really quiet! I'd stand on top of some glass, with a mic pressed against it, and we just had to make it break. We then put salt and tiles underneath the glass, too, so when you stand on it, you get this frozen ice-lake kind-of sound without actually having to freeze a thing.

We used a similar technique when working on [*Harry Potter and the Deathly Hallows*] when Harry meets a Patronus, but we adapted it for *Fable*.

Do games make you smarter?

Games often get blamed for making people unimaginative or lazy, but studies show the opposite!

Spatial intelligence
Neuroscientist Daphne Bavelier discovered that people who play games are more likely to notice small details, and can maintain their attention over a wider field of view.

Logical intelligence
Bavelier's study also concludes that gamers are able to display more rapid decision-making abilities than non-players, and can solve problems quicker and easier using abstract thinking.

Eyesight
People that play first-person shooting games tend to have better vision than those that don't, a University of Rochester study revealed. The games help boost your 'contrast sensitivity', meaning players can perceive finer differences between light and dark.

Sharpening skills
Games are used in training military personnel and game-like simulations aid practicing surgeons. This is because 'practice makes perfect' and the more times people perform a task, virtual or not, the better they become.

Social skills
A research review in the journal *American Psychologist* found that multiplayer games like *World of Warcraft* become virtual social communities that encourage cooperation, which can help the players develop social skills.

Brain 'age'
Believe it or not, playing a brain-teasing game for as little as two hours a week might prevent natural cognitive decline, according to a study carried out at the University of Iowa.

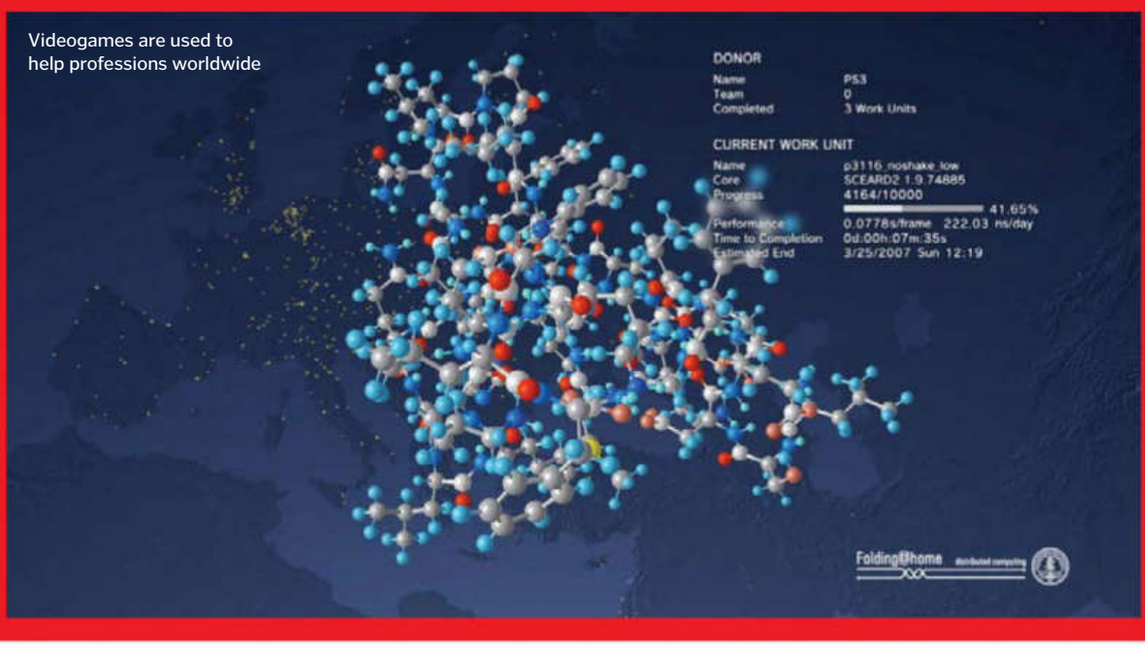
Problem solving
The *American Psychologist* also review found that games develop critical thinking skills by encouraging players to come up with creative solutions to problems, such as solving puzzles.

Motor skills
Researchers from Deakin University in Australia discovered that children between three and six years old, who played physically interactive games, showed more control over their limbs and improved motor skills compared to children that didn't.

Beyond games

Videogames and their tech aren't just used for entertainment; gaming interfaces are used to aid other professions in their roles. For example, an Xbox 360 game pad is used by the American military to control the High Energy Laser Mobile Demonstrator system, and the controllers that are used to pilot unmanned aerial drones are also modelled on game pads.

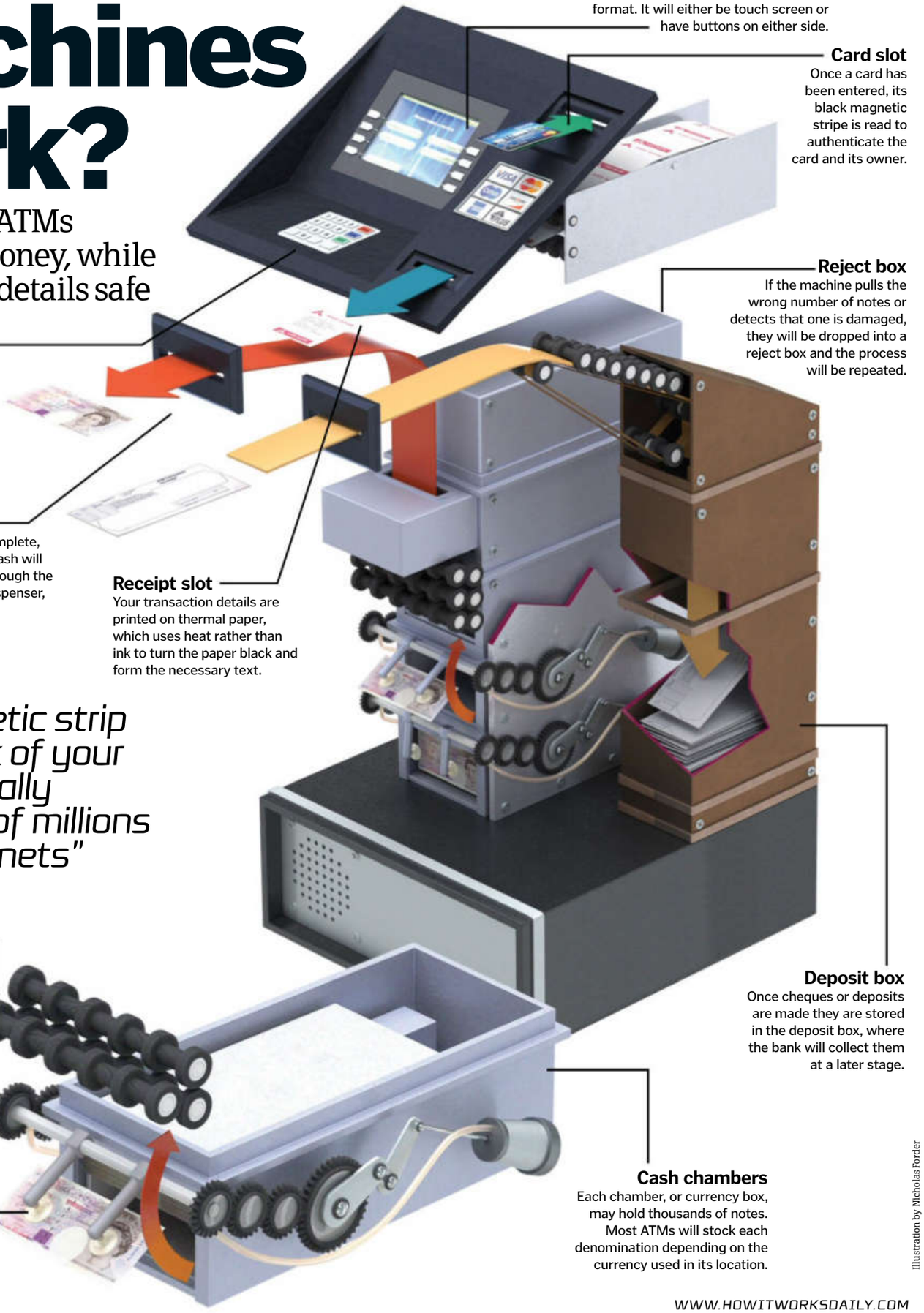
A project called 'Folding@home' used the processing power of your PS3 to help solve massive computational puzzles when the machine was not in use. *Minecraft* has been used by Britain's mapping agency, Ordnance Survey, to create a digital map of Great Britain using real-world geographical data.



Videogames are used to help professions worldwide

How do cash machines work?

Find out how ATMs access your money, while keeping your details safe



Screen
The screen, commonly an LCD on modern machines, will prompt the cardholder through the transaction in a step-by-step format. It will either be touch screen or have buttons on either side.

Card slot
Once a card has been entered, its black magnetic stripe is read to authenticate the card and its owner.

Reject box
If the machine pulls the wrong number of notes or detects that one is damaged, they will be dropped into a reject box and the process will be repeated.

Keypad
The keypad is where users enter their four-digit PIN. This is then sent to the cardholder's bank in an encrypted form in case someone intercepts it.

Cash dispenser
Once the transaction is complete, the requested amount of cash will travel up from the vault through the roller mechanism to the dispenser, where it can be collected.

Receipt slot
Your transaction details are printed on thermal paper, which uses heat rather than ink to turn the paper black and form the necessary text.

"The magnetic strip on the back of your card is actually composed of millions of tiny magnets"

Rollers
The rollers check the thickness of each note to make sure that two notes aren't stuck together, so the cardholder receives the correct amount of money.

Deposit box
Once cheques or deposits are made they are stored in the deposit box, where the bank will collect them at a later stage.

Suction cups
The suction cups pick up notes individually, before the rollers process them.

Cash chambers
Each chamber, or currency box, may hold thousands of notes. Most ATMs will stock each denomination depending on the currency used in its location.

Illustration by Nicholas Forder

It's somewhat hard to imagine our modern world without cash machines, yet they only became the norm during the 1970s. The first machine that dispensed cash was invented by John Shepperd-Barron and was installed outside a branch of Barclays Bank in Enfield, Greater London.

Today, they work to give us access to our money 24 hours a day in a multitude of locations, and are far more convenient than queuing in a bank. However, there are many challenges for them to overcome in order to provide the required level of service. They have to check that you and your card are legitimate, find your account information and carry out the transaction required, all while protecting the thousands of pounds stored inside its vault.

The magnetic strip on the back of your card may look like a solid black line, but it's actually composed of millions of tiny magnets, each one magnetised either north or south, which two magnetic readers understand like a binary code. The first reader confirms the card is real, while the second reads your account number and PIN, checking this against the code that you entered on the keypad.

Once your PIN is confirmed, the machine automatically connects to your bank's network which relays a signal back to the built-in vault, giving it a specific set of instructions. The ATM will then complete the transaction that has been requested. If you forget to take your cash for whatever reason, modern cash machines will swallow the money after a short period of time so you won't be out of pocket.

PIN code shields similar to the one pictured are one way of reducing fraud

There are numerous ways that cash machines can be tampered with, from hidden cameras to card traps, so it is best to take precautions

The rise of ATM fraudsters

Today our cash machines are constantly under threat from organised crime, with a number of techniques available to criminals that can quickly and cheaply access your card details. The skimmer attachment is one of the most commonly used scams, and involves a small device being fitted to the cash machine which will then read and record your card details. Coupled with this is often a hidden camera, cleverly concealed in panels above the machine or somewhere nearby to find out what your PIN code is. Card traps are also becoming increasingly popular – they work by trapping your card in the machine for the fraudster to collect at a later date. To combat these problems, the police recommend that you always remain vigilant when using a cash machine. By checking for anything unusual or out of the ordinary, you can spot most attempts to rip you off, especially if you use the cash point in question frequently. Make sure you cover your PIN at all times and be wary of any suspicious bystanders hanging around the ATM.

Cordless telephones

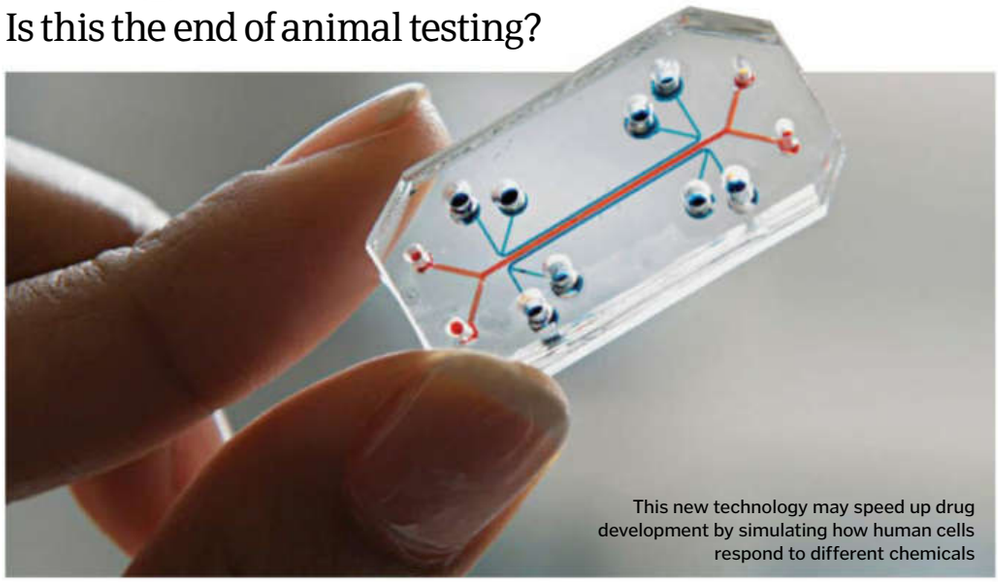
How digital cordless communication became a household essential

Cordless phones are one of those inventions that are hard to live without. Packed with technology, they originated in the 1980s and were the first devices to enable landline conversations to be taken all around the home. Made up of a handset and a base, the former relies on the latter to work. The base is plugged into the telephone jack and receives the incoming call as an electrical signal, which it then converts into a radio signal that it transmits to the handset. The radio signal gets reconverted into an electrical signal by the handset, where it is sent to the speaker and made audible. As you talk into the handset, your voice is broadcast as a radio signal to the base, where it is converted to an electrical signal and sent through the phone line.

Range, sound quality and sound security are all essentials, and have got better with time as analogue frequencies have been replaced with digital. Some long-range cordless phones enable you to make and receive calls even when you are 50 metres (164 feet) away from the base station.

Organs-on-chips

Is this the end of animal testing?

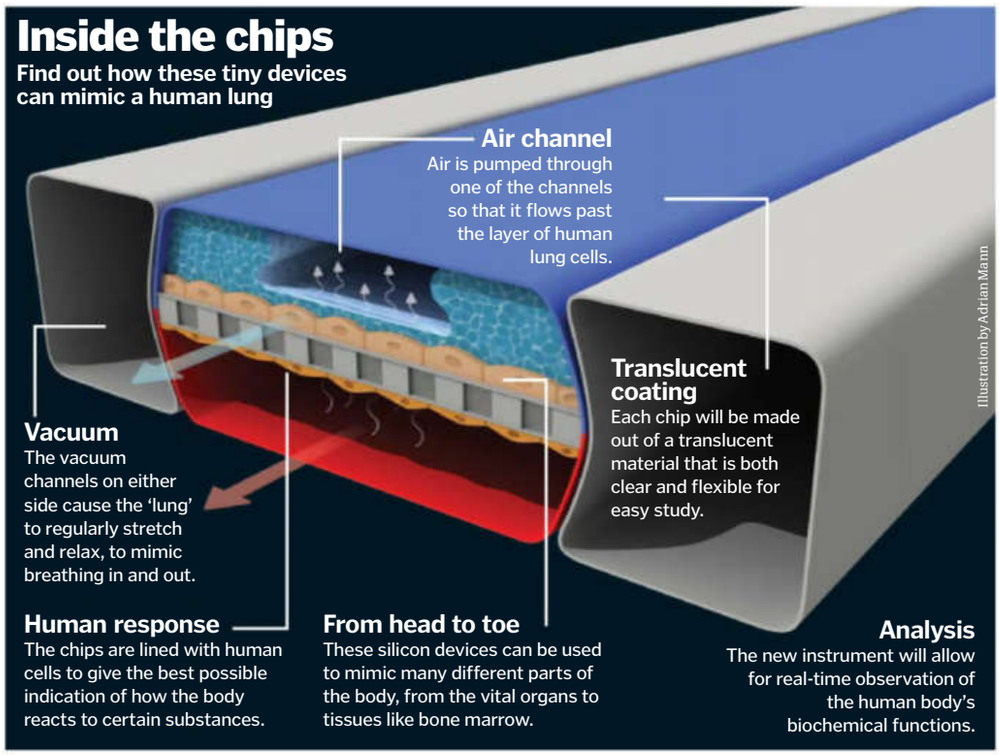


This new technology may speed up drug development by simulating how human cells respond to different chemicals

Designed to imitate the functions of complex organs such as the heart, lungs and intestines, these silicon microchips are only the size of a small USB stick, but could have the power to transform medicine. The chips are embedded with microfluidic channels, which are lined with human cells from particular organs. Chemicals can then be pumped through these tubes, enabling researchers to see how these 'organs' will react through a microscope.

The lung chip, for example, features human lung cells on one side of the chip and blood capillary cells on the other. These are divided by a porous membrane – a thin walled structure that enables air or liquid to pass through. Air runs through one side and a blood-like solution flows through the other, while a stretching motion generated by a vacuum replicates the mechanics of breathing.

Several different organs have been replicated so far by scientists at the Wyss Institute at Harvard University, who continue to test and evaluate the limits of their chips. It is hoped that these devices could be used to develop drugs without the need for animal testing.



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The Meccanoid

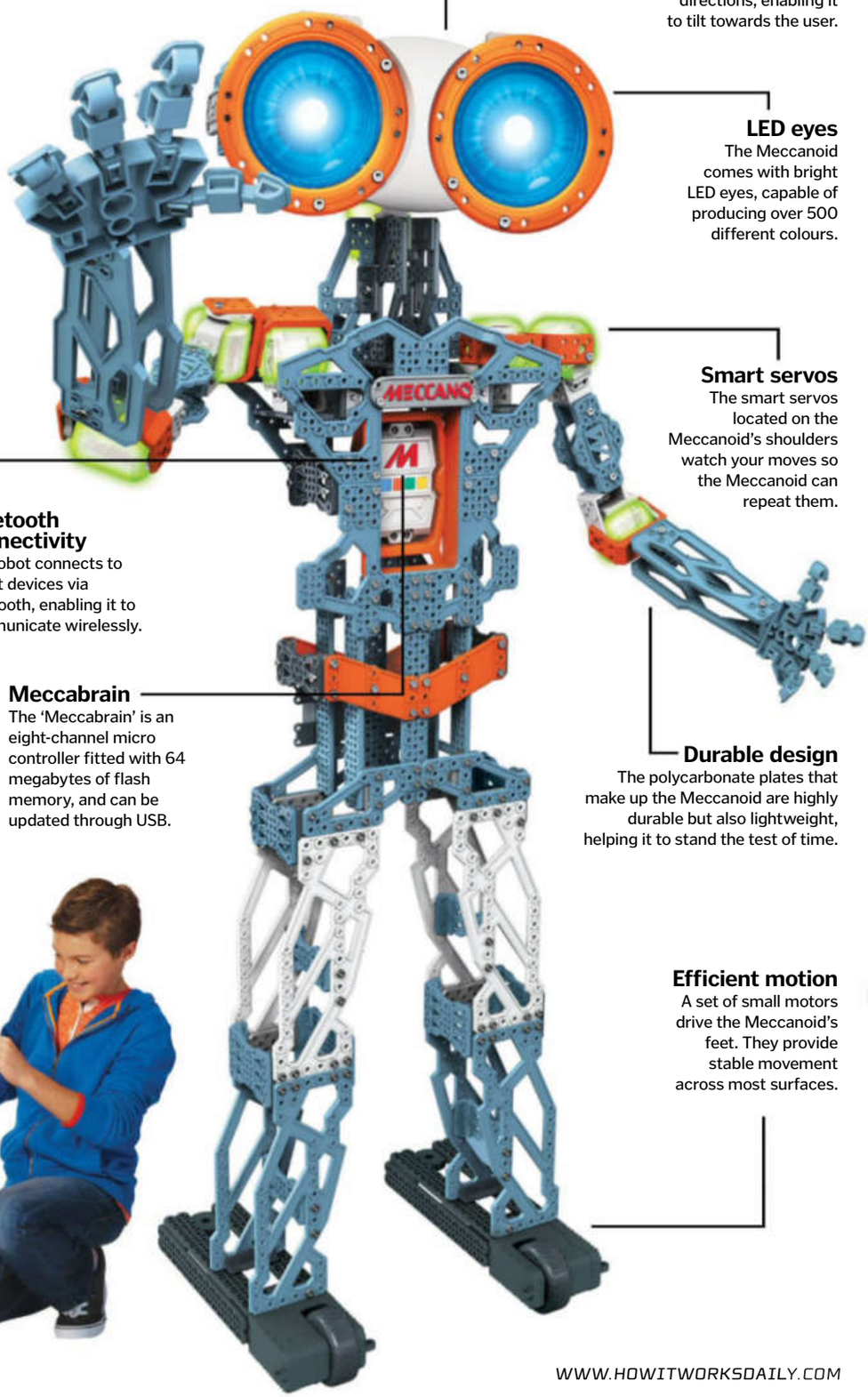
The personal robot that's much more than just a toy

For the past century, children around the world have enjoyed building trains, cranes and cars with the help of Meccano. With so many children now practically joined to their smartphone, Meccano have given their model construction set a technological makeover so that kids can now build their own fully interactive robot.

The Meccanoid features new polycarbonate plates which are compatible with the classic metal Meccano parts, and allow you to create a robotic companion full of personality and capable of responding to your instructions. The Meccanoid is available in two configurations, the G15 and the G15 KS. The G15 KS is the larger of the two, standing at an impressive height of almost 1.22 metres (four feet), built from over 1,100 pieces and ten motors. The smaller version is approximately half the size, built from 600 parts and six motors. The creators hope that this robot will not only be immensely fun to play with, but will also teach aspiring engineers the basics of programming, thanks to its simple buttons for accessing the Meccanoid's various functions. For more information on the Meccanoid, visit **www.meccano.com/meccanoid**.

Meccanoid mechanics

See the design features of Meccano's first venture into personal robotics



Responsive head
The Meccanoid G15 KS's head is articulated to move in many directions, enabling it to tilt towards the user.

LED eyes
The Meccanoid comes with bright LED eyes, capable of producing over 500 different colours.

Smart servos
The smart servos located on the Meccanoid's shoulders watch your moves so the Meccanoid can repeat them.

Bluetooth connectivity
The robot connects to smart devices via Bluetooth, enabling it to communicate wirelessly.

Meccabrain
The 'Meccabrain' is an eight-channel micro controller fitted with 64 megabytes of flash memory, and can be updated through USB.

Durable design
The polycarbonate plates that make up the Meccanoid are highly durable but also lightweight, helping it to stand the test of time.

Efficient motion
A set of small motors drive the Meccanoid's feet. They provide stable movement across most surfaces.

The Meccano Maker System

With Meccano's clever system, the construction possibilities are truly endless

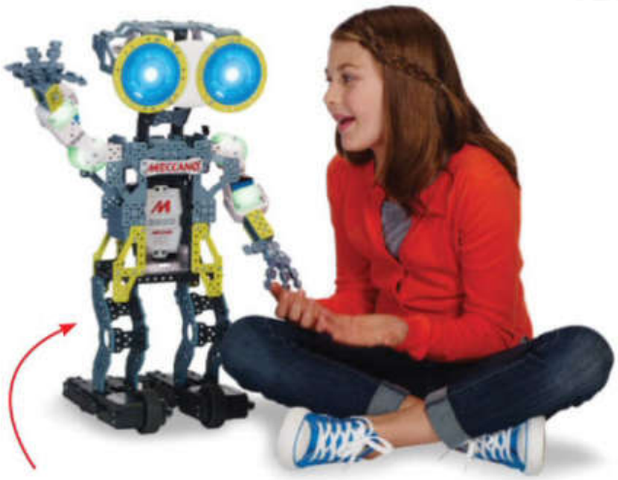
When it comes to construction, the Meccanoid is by no means a one-trick pony. It is fully customisable thanks to its 'Meccano Maker System', enabling you to build almost anything you can think of. As is tradition with Meccano, its parts are 100 per cent compatible with the classic Meccano parts, helping you to customise your creations further.

The larger Meccanoid G15 KS looks great when transformed into a dinosaur

How to program your Meccanoid

Learn the three unique types of programming that can operate the Meccanoid

"The Meccanoid features all the classic Meccano parts but functions as a walking and talking companion"



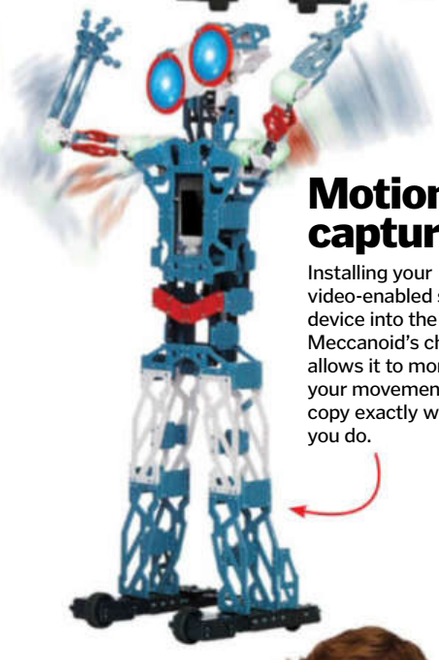
LIM: Learned Intelligent Movement

With the help of the clever 'LIM' technology, the Meccanoid can be programmed with a set of actions by simply moving the robot into the desired positions in the correct order. Then at the touch of a button, the Meccanoid will repeat these movements unaided. To go along with various movements, it can even be programmed to repeat sounds.

Voice recognition

Voice recognition plays a key role in the Meccanoid's programming. Both the G15 and the G15 KS will respond to more than 1,000 pre-programmed voice commands such as "walk forward", and can even be programmed to respond to an unlimited number of user-recorded voice commands. Both models of the Meccanoid are capable of telling jokes, saying fun facts, asking questions, and even starting conversations with the user. Remembering your name and birthday is another nice touch, showing that the creators really have tried to cover all bases.

The Meccanoid G15 may be smaller than its brother, but it provides just as much entertainment

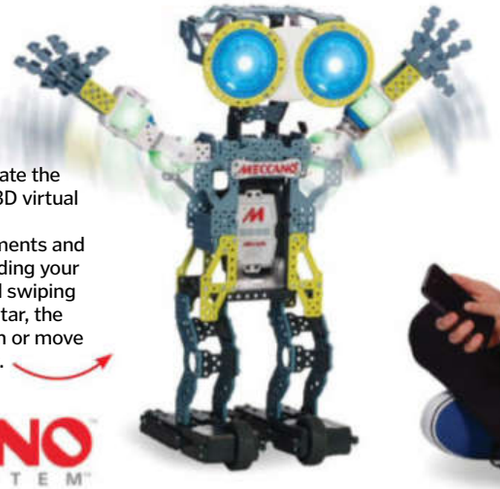


Motion capture

Installing your video-enabled smart device into the Meccanoid's chest allows it to monitor your movements and copy exactly what you do.

Ragdoll avatar

By connecting your smartphone up to your Meccanoid, you can operate the physical robot using the 3D virtual model, enabling it to be programmed with movements and sounds wirelessly. By holding your smartphone or tablet and swiping the onscreen Ragdoll Avatar, the Meccanoid will twist, turn or move in any direction you want.

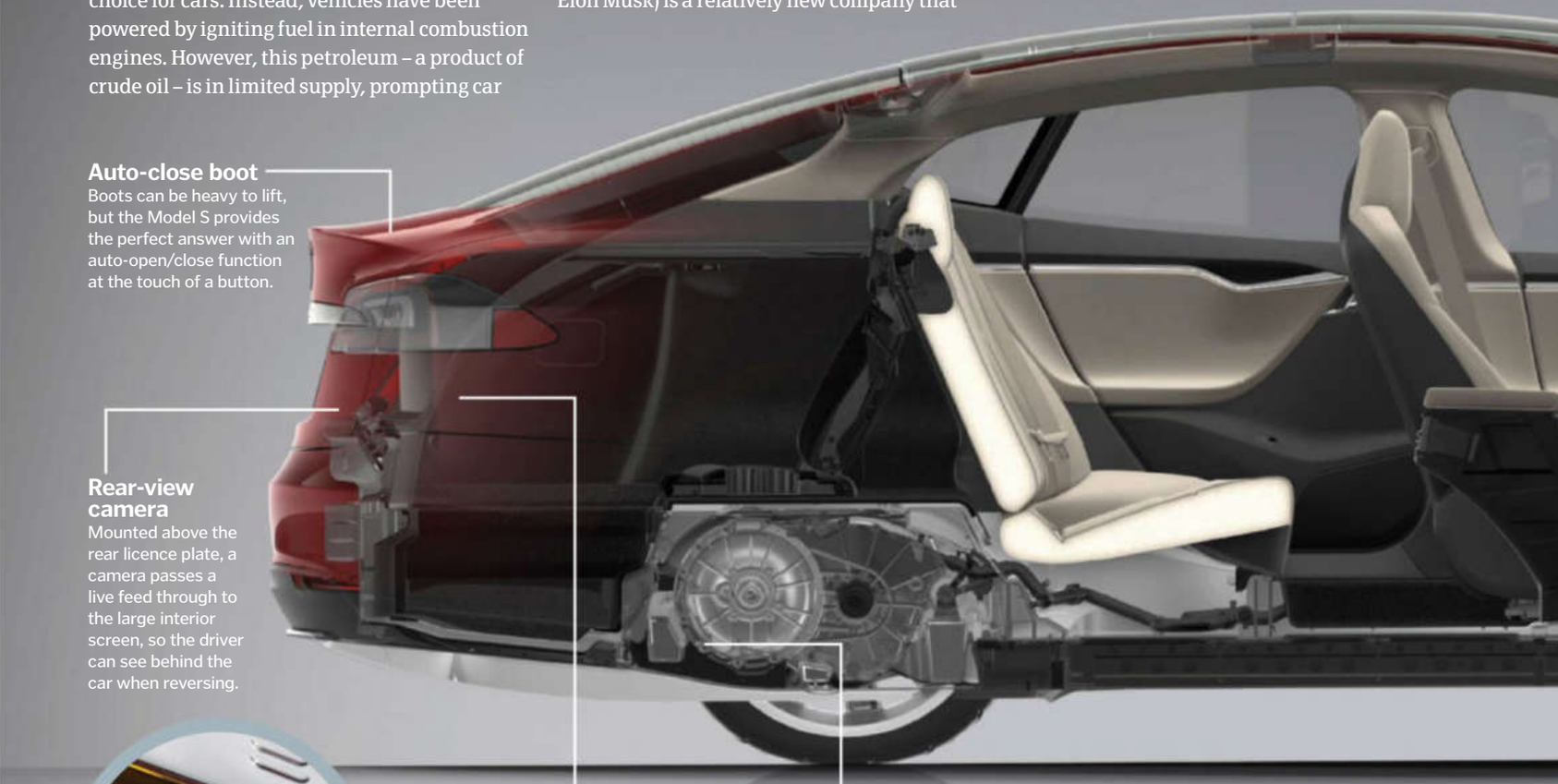


MECCANO MAKER SYSTEM

INSIDE THE TESLA MODEL S

They're the most talked-about electric car manufacturer in the world, but just what makes Tesla Motors so innovative?

The concept of an electric car is not a new idea. Manufacturers were building them as far back as the 19th century, with Porsche building their first car, the electric P1, in 1898. Despite its deep-rooted foundation with vehicles, electricity was never substantially developed enough to become the power of choice for cars. Instead, vehicles have been powered by igniting fuel in internal combustion engines. However, this petroleum – a product of crude oil – is in limited supply, prompting car manufacturers to look at alternative forms of power, such as hydrogen and hybrid systems. Electricity has once again come to the fore, and California-based Tesla Motors is leading the charge for this viable, greener technology in our modern world. Unlike other manufacturers, Tesla (led by renowned entrepreneur and CEO Elon Musk) is a relatively new company that specifically produces electric vehicles. Their innovation and commitment to making futuristic cars has ensured that this small Californian company has garnered an impressive reputation across the globe, and we will show you why...



Auto-close boot
Boots can be heavy to lift, but the Model S provides the perfect answer with an auto-open/close function at the touch of a button.

Rear-view camera
Mounted above the rear licence plate, a camera passes a live feed through to the large interior screen, so the driver can see behind the car when reversing.

More storage space
With no engine to speak of, the Model S actually has two luggage storage compartments: one in the front of the car under the conventional 'hood', and the other in the rear.

"Tesla Motors is leading the charge for this viable, greener technology"

Regenerative brakes

As well as using electricity, the Model S is also able to generate it while driving through town. When a driver lifts off the accelerator pedal, gentle braking is automatically applied, and the energy harvested by the brakes is then fed back into the motor to reuse. This is a key component in helping the Model S to maintain its exceptional range.

Software updates

One of the most creative innovations over a conventional car is Tesla's use of software updates. This is all done over-the-air, meaning cool new features can be added to the Model S overnight. An example of this is the addition of the 'creep' function when releasing the brake pedal in traffic, which was added after Tesla consulted with Model S owners on how to improve the driving experience.

Preconditioning

Thanks to the intuitive Tesla Model S app, owners can precondition the on-board climate of their vehicle remotely, so the car reaches the perfect temperature by the time they enter.

No more keys!

The Model S doesn't use a conventional car key as we know it. Instead, owners are presented with a small fob – sculpted to mimic the shape of the car itself – which has a built-in transmitter that talks to the car via onboard sensors. This means an owner only needs to have the key on their person and, when they approach the car, the door handles pop out and the car is ready to start.

Interactive interface

The huge dash-mounted touchscreen is the technological epicentre, providing access to navigation, entertainment, HVAC controls and more.

Quiet tyres

With a noisy engine replaced by a beautifully silent motor, the Model S glides along the road with virtually no audible soundtrack. From inside the car, the only noise that remains (with the radio switched off) is rolling road noise. To combat this, ContiSilent tyres from Continental are used, which have an extra layer of foam inside to reduce the noise it produces when rolling along a surface.

Air suspension

Want to lower the Model S for sportier handling or raise it to clear a steep driveway? This can be done with a tap of the dash-mounted touchscreen.

The Model S is simple and speedy to charge up, with free use of Tesla Superchargers

Inside the Tesla factory

Here's how the innovative Model S is put together in Fremont, California

Tesla Motors can lay claim to producing some of the most innovative and technically advanced electric vehicles on the planet. Currently, Tesla produce one car – the Model S – which is available with a variety of power and drive options, however, a Model X SUV is planned for 2016. This Model X will be manufactured alongside the existing Model S from Tesla's main factory in Fremont, California.

The facility was once home to General Motors and Toyota, producing half a million vehicles per year. Tesla Motors purchased the premises on Fremont Boulevard in 2010. They transformed the building into a factory that's as technologically advanced as the cars that roll out of it, all on a site that covers an area of 492,000 square metres (5.3 million square feet), used for both manufacturing and office space. Old assembly equipment was torn out and robots were installed that can perform complex functions, from assembling the chassis to welding and laser-cutting parts. Each one is named after an *X-Men* character, as they have the 'superpowers' to lift and manoeuvre entire cars with ultimate precision.

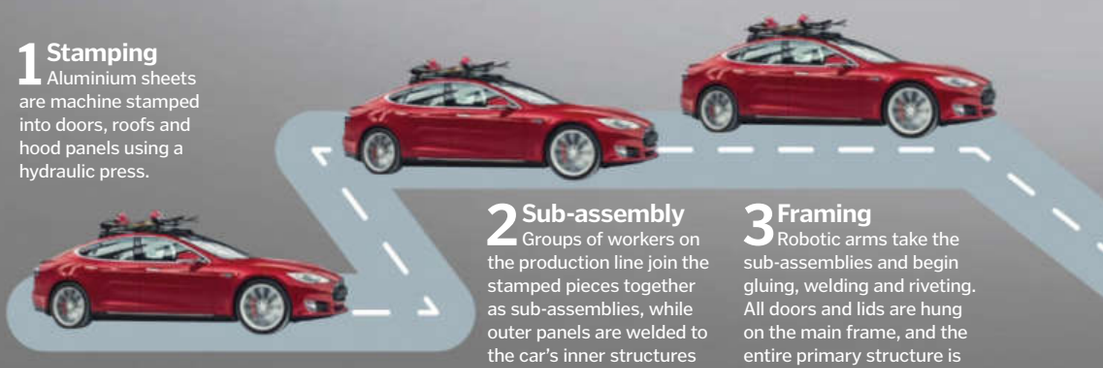
The factory floor itself is split down into five sections: stamping, assembly, body, paint and plastics. Every part of the Model S build process is carried out at the factory in California, from the early panel beating to final test-driving. State-of-the-art technology used by Tesla in the production of its cars also means high efficiency, reducing its carbon footprint. This includes basic measures, such as replacing fluorescent lights with energy-saving LED lamps, all the way to using ultrasonic waves inside the car instead of wasting gallons of water for a leak test. They also use powder coatings for the primer and clear coat layers instead of traditional liquid paints (which contain harmful compounds), another modification that helps lower emissions.

The addition of advanced robots and conveyors enables the factory to process one million battery cells every day. Soon it is hoped that the robots will also be able to install the battery packs in the cars, which will relieve factory workers of one of the most labour-intensive jobs in the process. Currently, Tesla can produce up to 100,000 vehicles annually. Not bad for a company that is less than 15 years old.

A robot named Xavier lifts cars down to the floor so the other 'superhero' machines can assemble them

From factory floor to your driveway

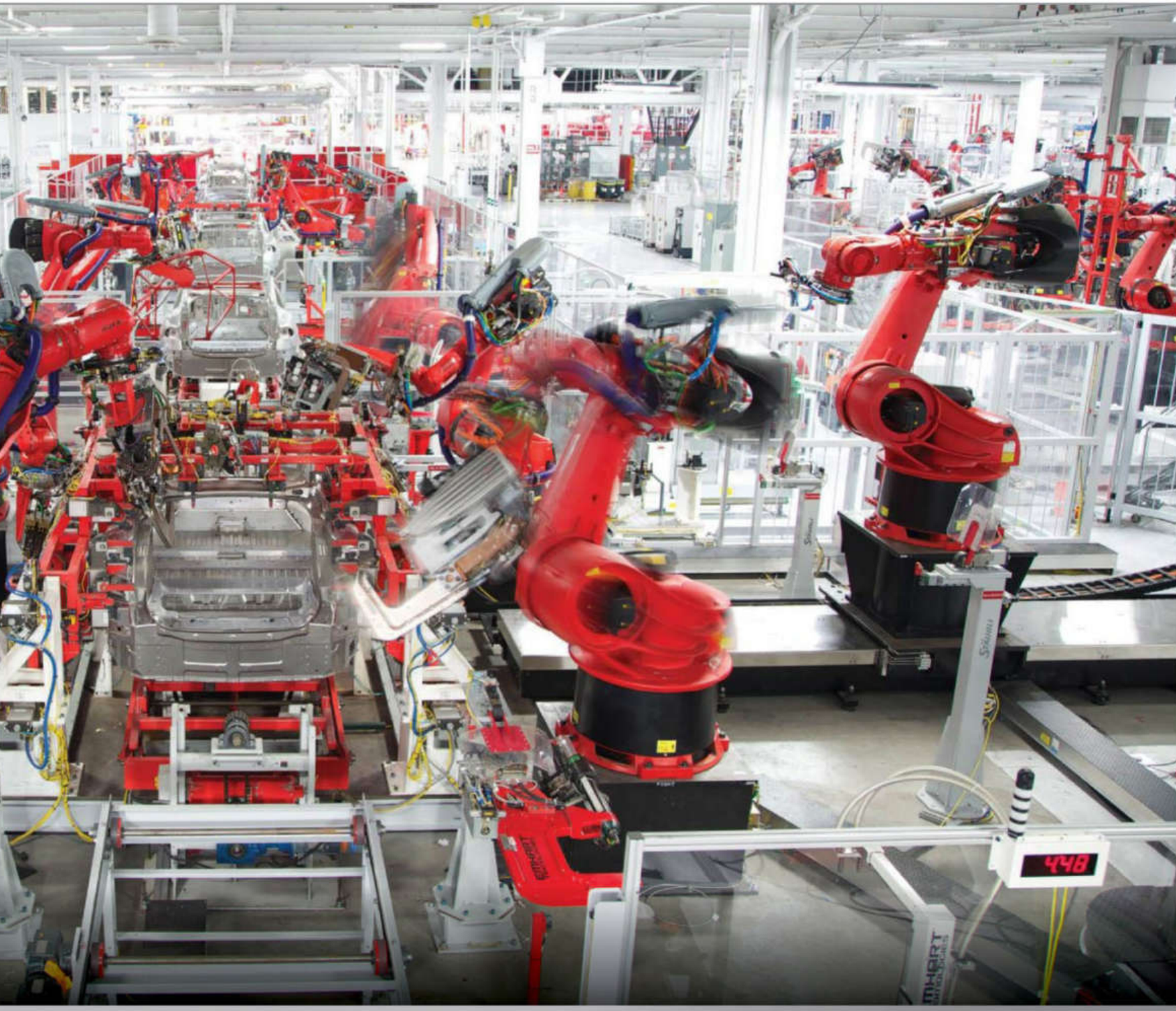
Discover what it takes to create a Tesla Model S



1 Stamping
Aluminium sheets are machine stamped into doors, roofs and hood panels using a hydraulic press.

2 Sub-assembly
Groups of workers on the production line join the stamped pieces together as sub-assemblies, while outer panels are welded to the car's inner structures for strength and safety.

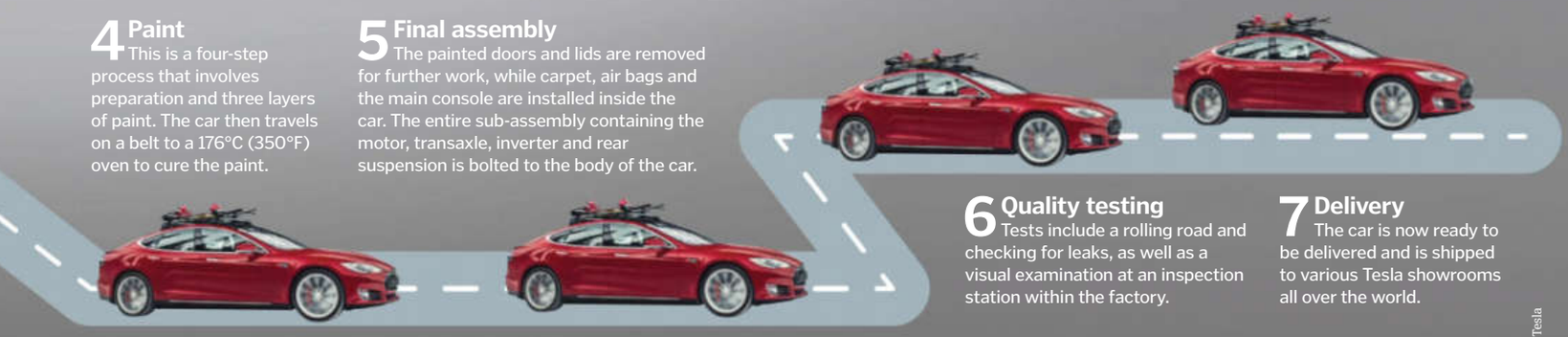
3 Framing
Robotic arms take the sub-assemblies and begin gluing, welding and riveting. All doors and lids are hung on the main frame, and the entire primary structure is checked for imperfections.



"Old assembly equipment was torn out and robots were installed"

4 Paint
This is a four-step process that involves preparation and three layers of paint. The car then travels on a belt to a 176°C (350°F) oven to cure the paint.

5 Final assembly
The painted doors and lids are removed for further work, while carpet, air bags and the main console are installed inside the car. The entire sub-assembly containing the motor, transaxle, inverter and rear suspension is bolted to the body of the car.



6 Quality testing
Tests include a rolling road and checking for leaks, as well as a visual examination at an inspection station within the factory.

7 Delivery
The car is now ready to be delivered and is shipped to various Tesla showrooms all over the world.

Automated features

How the Model S can switch lanes and park by itself

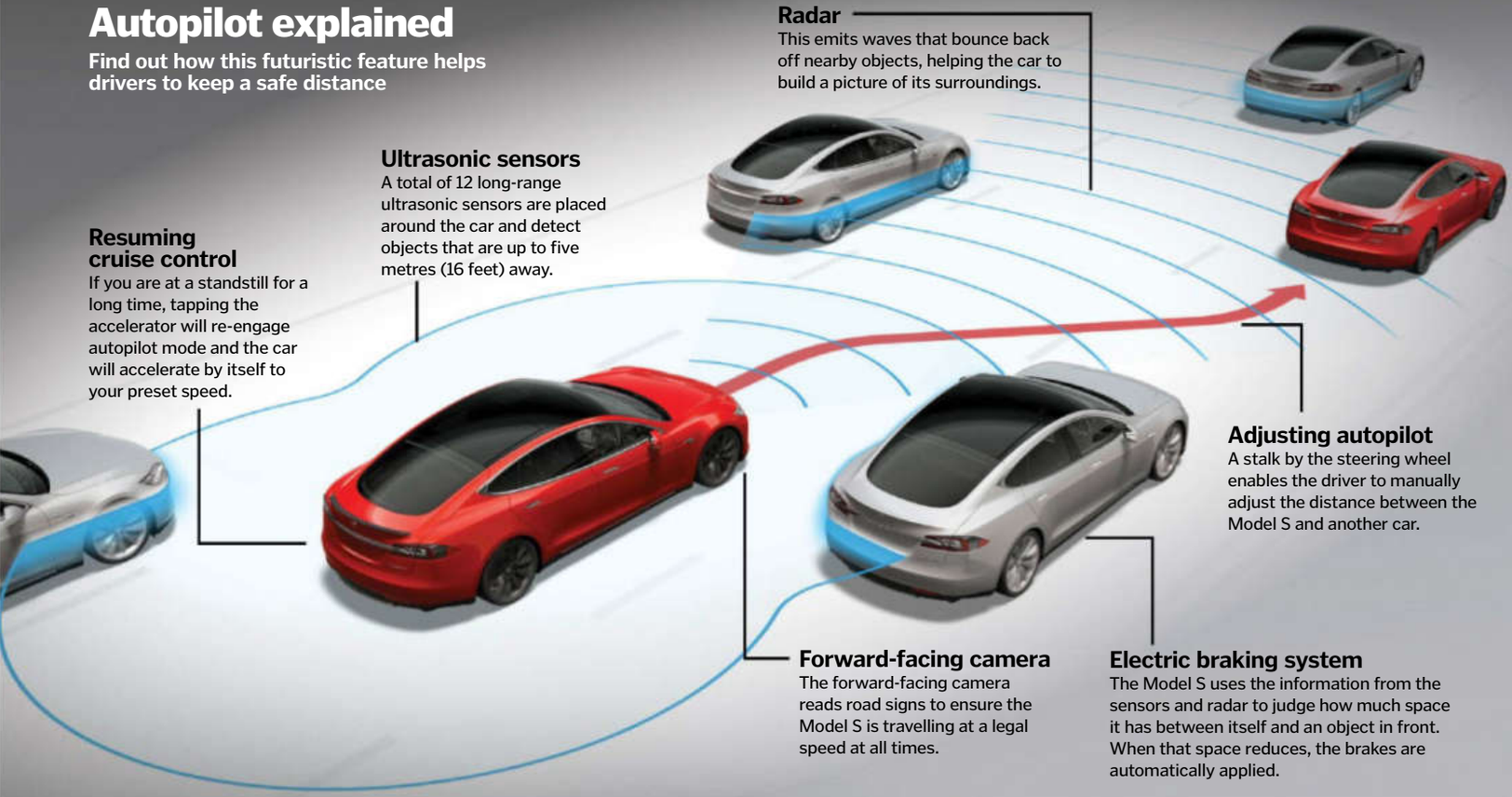
Although not quite a driverless car, the Model S does boast an array of automated features including autopilot, lane change assist and automated parking. The most revolutionary of these, autopilot, works by utilising a forward radar, 12 long-range ultrasonic sensors positioned around the car, a forward-facing camera and a digitally-controlled electric braking system.

The camera reads road signs and checks for objects in front of the Model S' projected line, while the radar and ultrasonic sensors constantly sense five metres (16 feet) around the car to check for objects such as cars in traffic. The data is fed to the car's engine control unit (ECU), which determines what lane or path the Model S needs to take. The idea is to take the strain out of situations such as congestion, offering increased comfort for the driver.

Similarly, the software and hardware is able to steer to keep the Model S within a designated lane, or even change lanes with just a tap of a turn signal, all while managing speed by reading road signs. Automatic parking is also possible under the same technology. The car will notify the driver when it detects an available parking space and be capable of smoothy manoeuvring into it.

Autopilot explained

Find out how this futuristic feature helps drivers to keep a safe distance



Radar
This emits waves that bounce back off nearby objects, helping the car to build a picture of its surroundings.

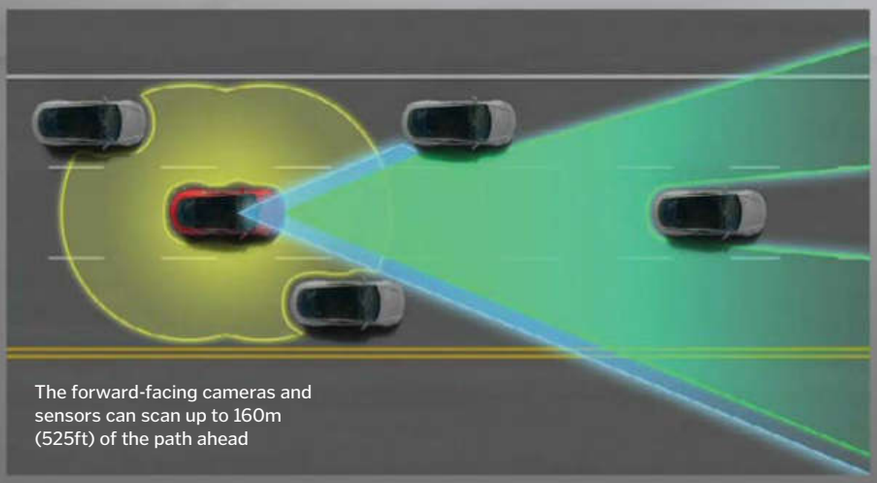
Ultrasonic sensors
A total of 12 long-range ultrasonic sensors are placed around the car and detect objects that are up to five metres (16 feet) away.

Resuming cruise control
If you are at a standstill for a long time, tapping the accelerator will re-engage autopilot mode and the car will accelerate by itself to your preset speed.

Adjusting autopilot
A stalk by the steering wheel enables the driver to manually adjust the distance between the Model S and another car.

Forward-facing camera
The forward-facing camera reads road signs to ensure the Model S is travelling at a legal speed at all times.

Electric braking system
The Model S uses the information from the sensors and radar to judge how much space it has between itself and an object in front. When that space reduces, the brakes are automatically applied.



The forward-facing cameras and sensors can scan up to 160m (525ft) of the path ahead

The Speed Assist function makes sure that the Model S keeps within the speed limit of the road

In the driver's seat

It may look like a conventional car from the outside, but the interior is laden with next-gen tech

Aside from there being no transmission tunnel running through the middle of the car (or even a gear stick for that matter) offering up more space, the interior is akin to that of a conventional vehicle. There are two seats up front, a rear bench in the back, and even an extra two rear-facing child seats in the boot space, should you wish to pay the optional £2,500 (nearly $4,000). However, the genius of the Model S lies with the huge 43-centimetre (17-inch) touchscreen in the centre of its dashboard. This interface is the main control hub for the entire car: the driver operates the touchscreen to access a variety of menus and settings, which control everything from opening the sunroof to providing satellite navigation.

On purchase of a vehicle, an owner is encouraged to download the Tesla Model S app, which lets you precondition the car's climate ready for your arrival, as well as flash the headlights or honk the horn – useful if your Tesla is parked in a busy multistorey car park. The app also provides a live location of the car's whereabouts via a satellite view powered by Google, ideal in the event of the car being stolen. Added to this, the app remotely notifies the owner when the Model S has finished charging, aiding the efficiency of the car in fitting in with the driver's day-to-day lifestyle.

The touchscreen is the focal point of the Model S' interior, negating the need for a plethora of controls

The Tesla map enables you to locate nearby charging stations

Q&A with Tesla UK's Georg Ell, country director

What do you think is the biggest advantage of owning a Tesla right at this moment?
It's the opportunity to be part of something that is shaping the future of motoring. It's future-proof, fun, exciting and safe at the same time. In 200 years from now, people will say Tesla was the [point] where we, as a planet, decided to turn our back on internal combustion engines that poison our air and damage the atmosphere. The quality of air is so bad that 50,000 people die per year due to poor air quality. Tesla is leading the change: people will soon look at motoring today much in the same way as when they think back to a time when smoking on aeroplanes and in pubs was permitted. It's a slice of the future, today.

How will you ensure a Model S is still on the road in ten years' time?
Because there are so few elements to a Tesla. It's more viable than a conventional car as the system is simpler: all that's left on our car when stripped back is a single moving part – the motor. This makes it far more easier to maintain financially than a conventional internal combustion-engined vehicle.

Lithium-ion batteries are known to deteriorate after a number of charges. What is Tesla doing to combat this?
Tesla currently gives an eight-year, unlimited mileage warranty on the battery and drivetrain. We're also developing a drivetrain that can achieve a million miles! Batteries will have an element of degradation, about one per cent per 10,000 miles, but our battery capacity is improving year-on-year by five per cent. We are also working on a system where Tesla owners can pay to upgrade their battery in future, should they wish. We also guarantee to buy a customer's car back from them in three years' time, and that's at a minimum of 50 per cent of the value of the car.

What are the greatest challenges for Tesla over the next five years?
A lot of it comes down to our own execution of following the plan and doing a good job. We're doing a lot with consumers, government and the wider industry to show our cars are more viable and better than a conventional car. The increase in consumer acceptance will grow competition and we welcome that. We are a drop in the ocean in terms of our size as an automotive company, but the pie will get bigger. National government is very excited about electric cars, we just need to ensure [that] local governments are equally [as] excited, helping us put more chargers in the street to ensure more people can feasibly drive our cars.

How the CYG-11 can fly and float

This clever new craft could totally change the tide for future travel

The travel industry is no stranger to vehicles that can multi-task when it comes to operating on various terrains and atmospheres. We've previously seen amphibious vehicles or even planes that can land or take off on sea, but the CYG-11 craft has gone one step further by being able to either fly in the air or 'float' on the water's surface. The Chinese-built CYG-11 'seaplane' is able to do this, thanks to clever re-engineering of a small propeller plane (which takes care of the flying side of its duties), enabling the craft to 'float' on a cushion of air above the sea. This means the craft can save money and space for owners who don't need to purchase both a boat and a plane for their travels, and also opens a new way of getting to destinations that were previously difficult to reach. The floating aspect of the seaplane works by drawing on the wing-in-ground effect, increasing lift and reducing drag when an aircraft's wings are close to the ground. This is done simply by mounting the wings lower down on the fuselage of the aircraft, enabling the plane to effectively float on a cushion of air.

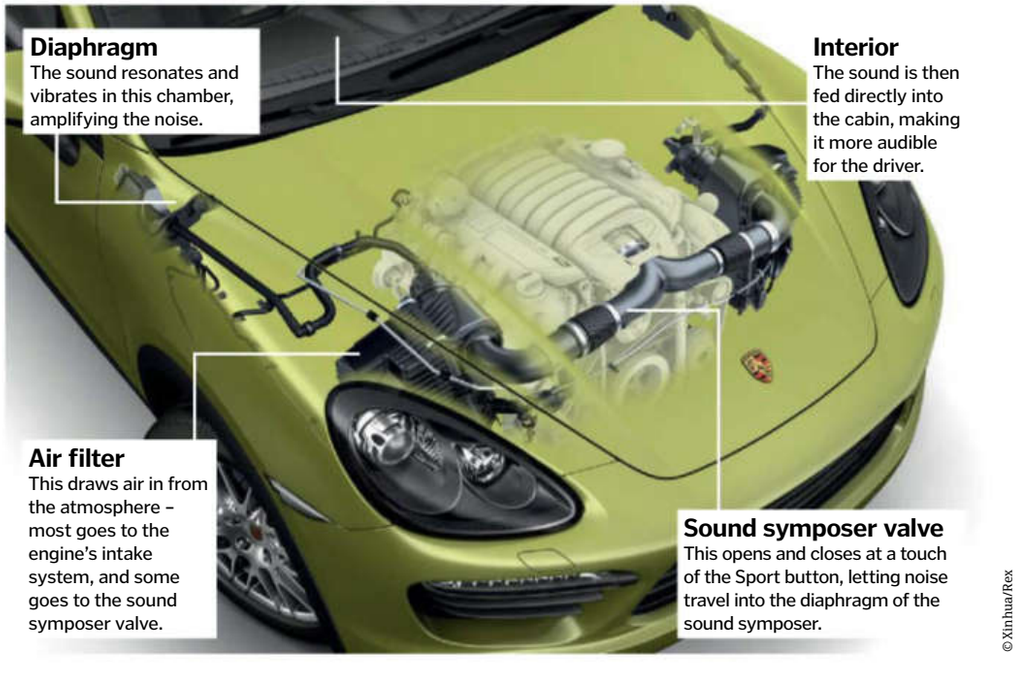
The CYG-11 craft can reach a top speed of 250km/h (155mph)

Science of sound symposers

These simple devices make sports cars sound even better

As sports car engines have become cleaner, they have also become quieter, particularly as vehicles switch to turbocharged engines in order to keep emissions down. However, some owners still want to hear the roar of that hard-working engine during performance driving, and it's here where the introduction of a sound symposer saves the day.

In essence, a sound symposer projects noise – but not fumes – from the exhaust straight into the cabin of a car. Inside the Porsche 911, an acoustic channel picks up vibrations from the engine, which are reinforced by a membrane and transmitted as sound into the cabin. To deactivate this, drivers can depress the Sport button, which closes a valve in the channel and reduces the roar of the engine.



NASCAR haulers

How this 18-wheeler transports race cars and more

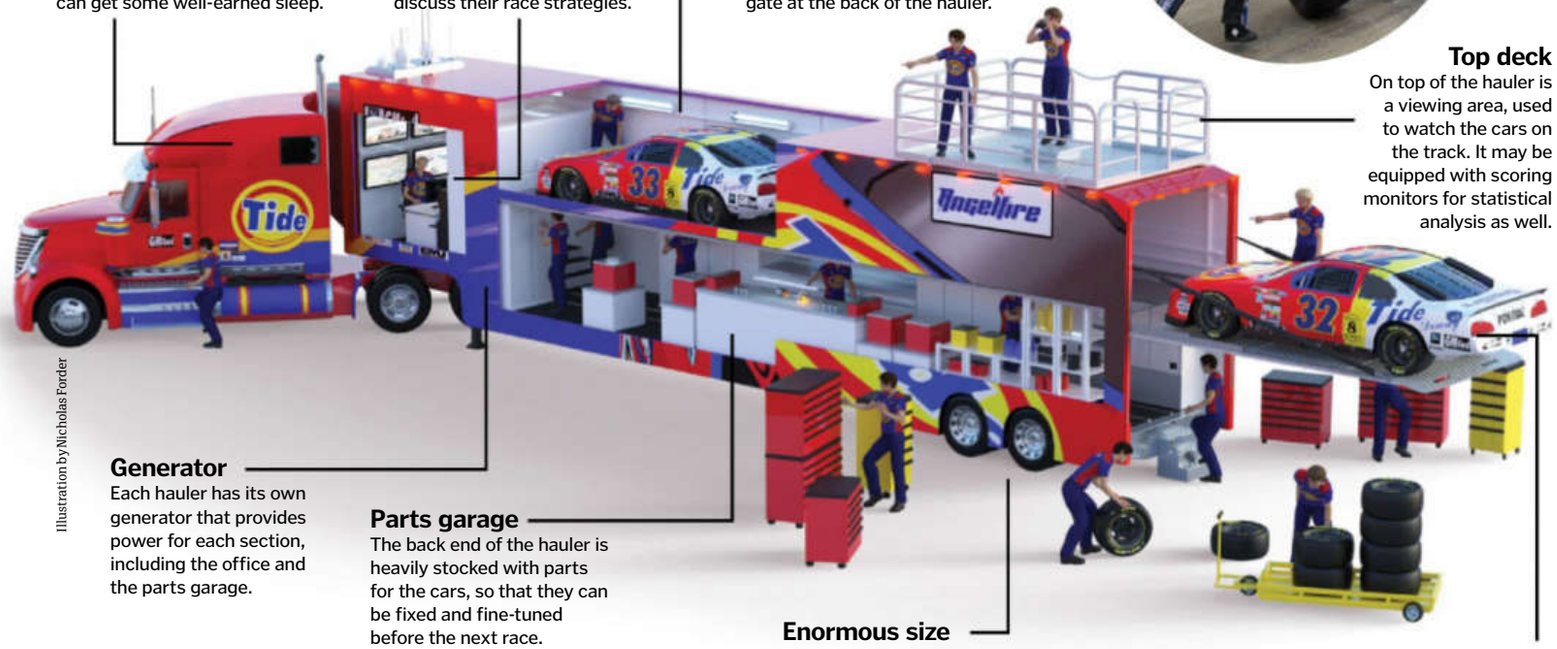
Over the years NASCAR has become a huge part of American sporting culture. Founded in 1947, it now sanctions more than 1,200 races across America, Canada, Mexico and Europe.

Getting the highly specialised race cars from one race to another presents the teams with a problem. You won't see a race car being driven on normal roads, and since the NASCAR races are so spread out across America, they have to be transported in a specialised hauler to each race venue. These haulers do much more than simply transport the cars; they function as repair shops, restaurants, meeting rooms, viewing platforms and storage facilities.

As every racetrack on the calendar is different, each NASCAR team will alter the setup of their cars depending on the conditions. This means that every car has to return to the team's base after each race before it can be transported to the next. Once it gets back to base, every single item on board the hauler is removed, before being either cleaned or replaced and then loaded back on. This equates to around 10,000 items – comparable to packing and unpacking a four-bedroom house every week for 38 weeks a year. Without the haulers, the drivers would have no feasible way of transporting their cars, and would likely be ill-prepared for their next race.

Inside the race shop on wheels

Discover just how much these haulers can store inside them



Sleeper cab
The front cabin has two beds behind the driver and passenger seats, so that the person who isn't driving can get some well-earned sleep.

Fully equipped office
Towards the front of the hauler is the office area, so the team have somewhere to discuss their race strategies.

Car bay
This level of the transporter holds two race cars, which are loaded using a hydraulic lift gate at the back of the hauler.

Top deck
On top of the hauler is a viewing area, used to watch the cars on the track. It may be equipped with scoring monitors for statistical analysis as well.

Generator
Each hauler has its own generator that provides power for each section, including the office and the parts garage.

Parts garage
The back end of the hauler is heavily stocked with parts for the cars, so that they can be fixed and fine-tuned before the next race.

Enormous size
Every hauler is roughly 24m (80ft) long, and can weigh as much as 36tn.

Matching design
As each NASCAR hauler is team (and driver) specific, the outside of the truck will match the design of the cars inside.

Illustration by Nicholas Forder

Life on the African savannah

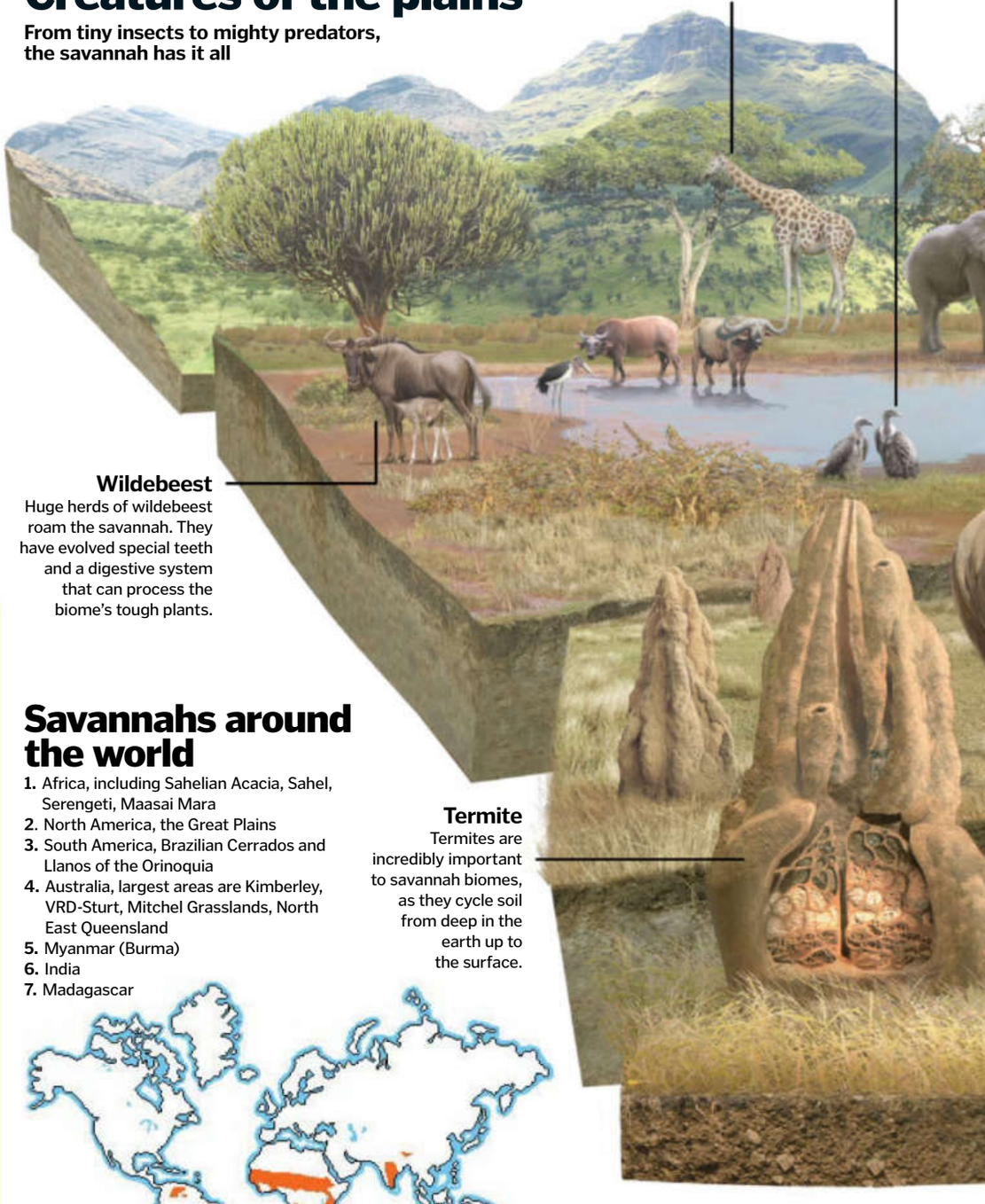
These majestic plains hold the secret to a delicately balanced ecosystem that supports the largest beasts on land

The savannah environment is a huge expanse of wide-open grassland that is home to a web of incredible plants and animals. Formed exclusively around the tropics, savannahs are characterised by just enough rainfall in the wet season to enable plants to flourish, yet not enough for a rainforest, and almost arid conditions in the dry season, but not dry enough to form a desert. The plants and animals that live here have developed amazing means of coping with this extreme environment.

Around the world, savannahs are known by different names; in Asia they are 'steppes', they are 'prairies' in North America, and in Australia they are 'rangelands'. Usually only African grasslands are given the name 'savannah', and one of the most famous is the Serengeti Plains in Tanzania. This ecosystem is home to some of Earth's most incredible creatures: big cats, elephants, rhinos and giraffes to name just a select few.

Creatures of the plains

From tiny insects to mighty predators, the savannah has it all



Vulture
Feeding on carrion, the vulture's massive wings enable it to soar above the ground, carefully searching for its next meal.

Giraffe
The giraffe is perfectly formed to browse the tallest trees for tasty morsels, then strip stems with its tough tongue.

Wildebeest
Huge herds of wildebeest roam the savannah. They have evolved special teeth and a digestive system that can process the biome's tough plants.

Termite
Termites are incredibly important to savannah biomes, as they cycle soil from deep in the earth up to the surface.

At the water hole

In the savannah, water holes are incredibly important features of the landscape, especially during the dry season. The seasonal or permanent pools of water, fed by rivers or aquifers, provide much-needed hydration for all animals of the savannah, sometimes drawing them in from many miles away.

Predator and prey alike gather to drink, and these connections keep the all-important savannah food web healthy. With all the animals gathering in one place, the predators have enough food but kill only what they need, which monitors the population naturally. Meanwhile the prey species are able to take a good long drink before moving on to their next destination.

Savannahs around the world

1. Africa, including Sahelian Acacia, Sahel, Serengeti, Maasai Mara
2. North America, the Great Plains
3. South America, Brazilian Cerrados and Llanos of the Orinoquia
4. Australia, largest areas are Kimberley, VRD-Sturt, Mitchel Grasslands, North East Queensland
5. Myanmar (Burma)
6. India
7. Madagascar

Africa's vast grasslands are home to some of the world's top predators

Elephant
The elephant's large ears and wrinkled skin keeps it cool, and its trunk grasps leaves and grasses for easy grazing.

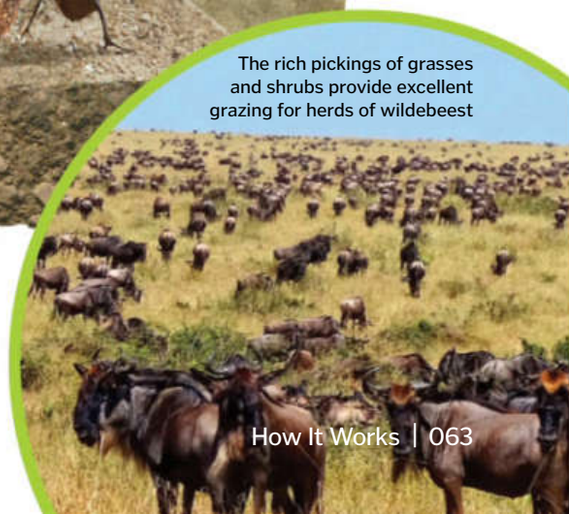
Zebra
A zebra herd's stripes are designed to confuse savannah predators, making it hard to distinguish one zebra from the next.

Scattered trees
Trees in the savannah are scattered in distribution, but provide vital shade, shelter and food for the animal inhabitants.

Rhinoceros
Herbivorous rhinos thrive on the rich grasslands; their broad snout and wide upper lip are perfectly adapted for grazing.

Lion
The African savannah's apex predator, a lion's sandy coloured coat helps it to camouflage in the grass to stalk prey.

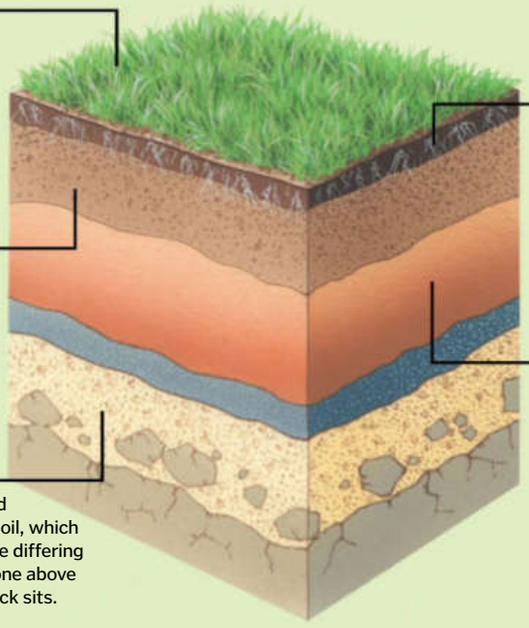
Dung beetle
These insects recycle the dung left by other savannah critters. They break down droppings and use them to lay eggs.



The rich pickings of grasses and shrubs provide excellent grazing for herds of wildebeest

Life on the ground

With a variable and distinctive soil profile, plants of the savannah have to be hardy to take root. Species must also be well-adapted to withstand extreme temperatures



Prevalence of grass
The fact that the laterite soil layer prevents trees from taking root is what favours the prevalence of so many grasses, which have much shorter root systems.

Laterite
Season upon season of rain and drought have caused the layers below the humus to become incredibly hard. The soil is so cemented that long tree roots are unable to penetrate it.

Horizons
The flow of nutrients head downwards through the soil, which creates horizons, each one differing in composition from the one above it. Below these, the bedrock sits.

Humus
The thinnest, uppermost layer in the soil profile is known as humus. It's made of the organic matter from decaying plants and animals, and provides vegetation with nutrients.

Distinctive red soil
During the wet season, intense leaching occurs where water draws out nutrients and chemical compounds from the soil. Iron oxide remains, which gives the soil its rusty colour.

Savannah foliage

Acacia tree
The Umbrella acacia tree is a symbol of the African savannah. Providing a source of food for many creatures, the seedpods actually grow better after passing through an animal's gut!

Rhodes grass
This tufty grass has a long root system that extracts water from the soil from over four metres (13 feet) deep. This enables the grass to withstand short drought and grazing from animals.

Red grass
Incredibly, this grass is not only resistant to fire, but regular burning enhances the grass' prevalence, providing it's not overgrazed. The species is a good indicator of a healthy savannah.

The grassland food chain

When you think of the word 'savannah', rolling African grasslands come to mind, along with Mufasa's words to Simba: "Everything the light touches is our kingdom." Disney's classic cartoon actually portrays an ecosystem that is very real. Africa's most famous savannah regions encompass the Serengeti National Park, the Ngorongoro Conservation Area, Maswa Game Reserve, the Loliondo, Grumeti and Ikorongo Controlled Areas and the Maasai Mara National Reserve. So important is the 30,000-square-kilometre (11,580-square-mile) region, that it contains two World Heritage Sites and two Biosphere Reserves.

The savannah biome has two distinct seasons, wet and dry, but there is still too little rain for many trees to grow, and so grasses and shrubs dominate the ecosystem. These hardy plants are able to support the great migration of herds of herbivorous animals, such as zebra and wildebeest, which travel en masse, chasing the rains and spurred on by the growth of new grass. Hungry predators like lions and cheetahs anticipate the arrival of these herds.

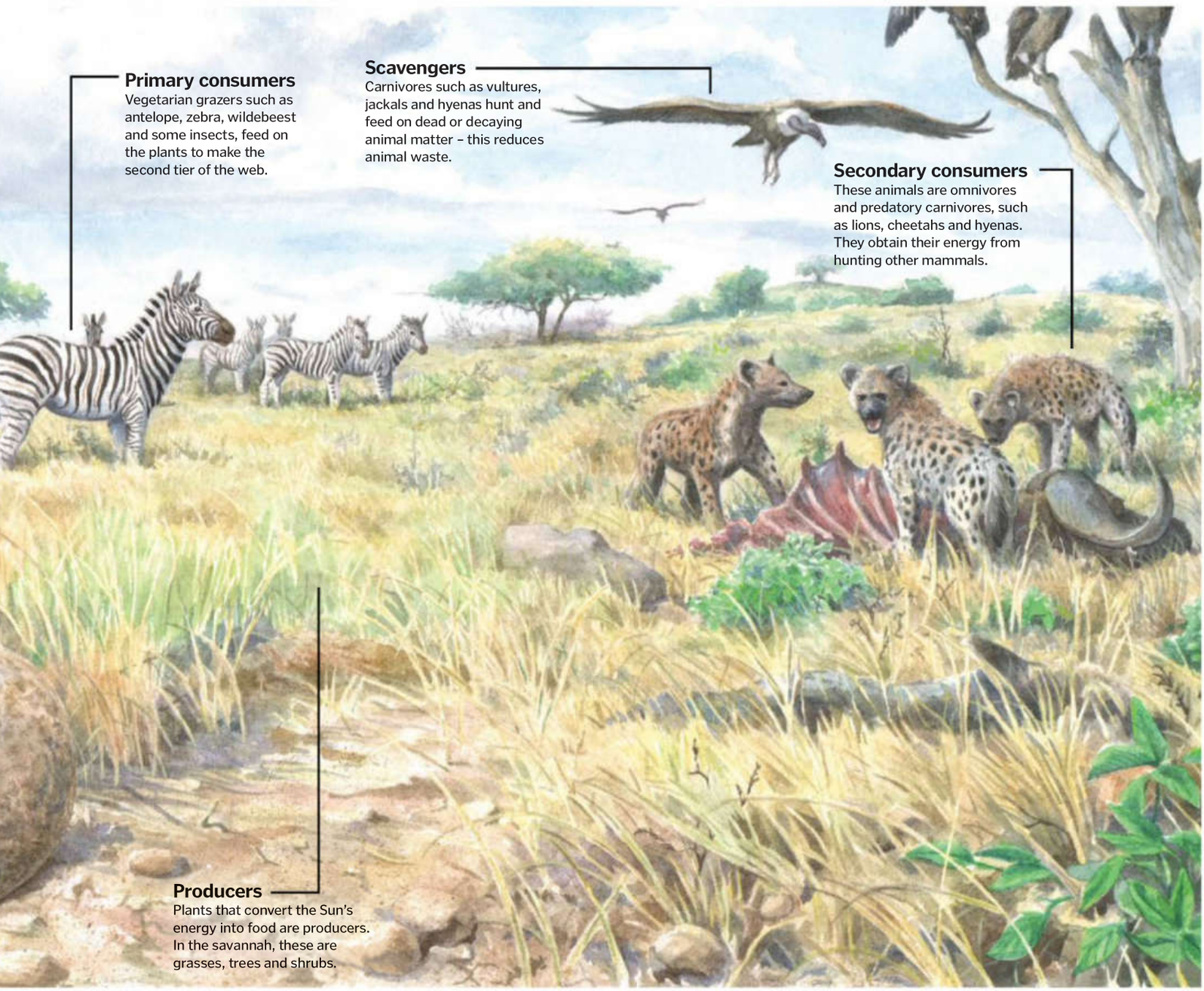
The savannah temperature remains fairly constant, and water holes can be found at various points across the plains (depending on the season), where many animals will gather to take a drink.

"There is still too little rain for many trees to grow, and so grasses and shrubs dominate the ecosystem"

The rainy season stretches from around November to May, and then the dry season sets in and temperatures remain around 27 degrees Celsius (81 degrees Fahrenheit).

The hoards of wildebeest, zebra and gazelle aren't the only animals willing to make a trek to find water. Elephants, living in their close-knit familial groups, can locate water holes up to 50 kilometres (31 miles) away in a relatively featureless environment. It's thought that they have excellent spatial memories, and can use this to recall where the water holes are in this radius. Safari goers to these regions have also noticed large ruts in the earth – this is caused by elephants using their long, strong tusks to dig down into the soil to search for water or to eat the soil to take in valuable nutrients.

Grasses are the prime source of food for the elephants and with so many other grazers, such as



Illustrations by Peter Scott / Ian Jackson / Art Agency

antelope and even rhinos, it's difficult to see how the grass doesn't simply wear out. The secret to this lies in both the grasses' biology and in the niches filled by each animal. Constant cutting of common savannah grass species, such as red grass or elephant grass, actually promotes fresh growth. This is because the grass growth occurs from the bottom of the shoot, so while they're nibbling away, the creatures are also gradually cultivating a grazing lawn. Different types of animals also have their own feeding techniques and take greenery from various levels. For example, giraffes browse for shoots, leaves and buds from high up in the trees, while zebras graze on the savannah floor. This means that there is little competition when it comes to finding vegetarian food.

Another rather more curious way that savannah grasses stay in healthy balance is through fire. During the dry season wildfires are a common occurrence and can burn away huge patches of grassland. However, instead of being devastating, these fires can return much-needed nutrients to the soil and encourage new growth. Many plant species are fireproof and can withstand the flames, and the fires also help to keep encroaching forests from taking over the grassland.

The hunters of the savannah are the big cats that sit at the very top of the food chain. Lions are, of course, the kings of the plains, but leopards, cheetah and African wild dogs are also high up in the savannah court. When the migratory herds arrive it provides rich pickings for these stealthy predators, who ensure that only the fittest prey survive. And where there are predators, there are scavengers, lurking on the sidelines. Spotted hyenas are skilful hunters but they're not picky eaters and will happily feast on the leftovers of other kills, as well as clean up any natural deaths. A very tough digestive tract enables the hyena to devour just about anything, and items that can't be digested are swiftly regurgitated.

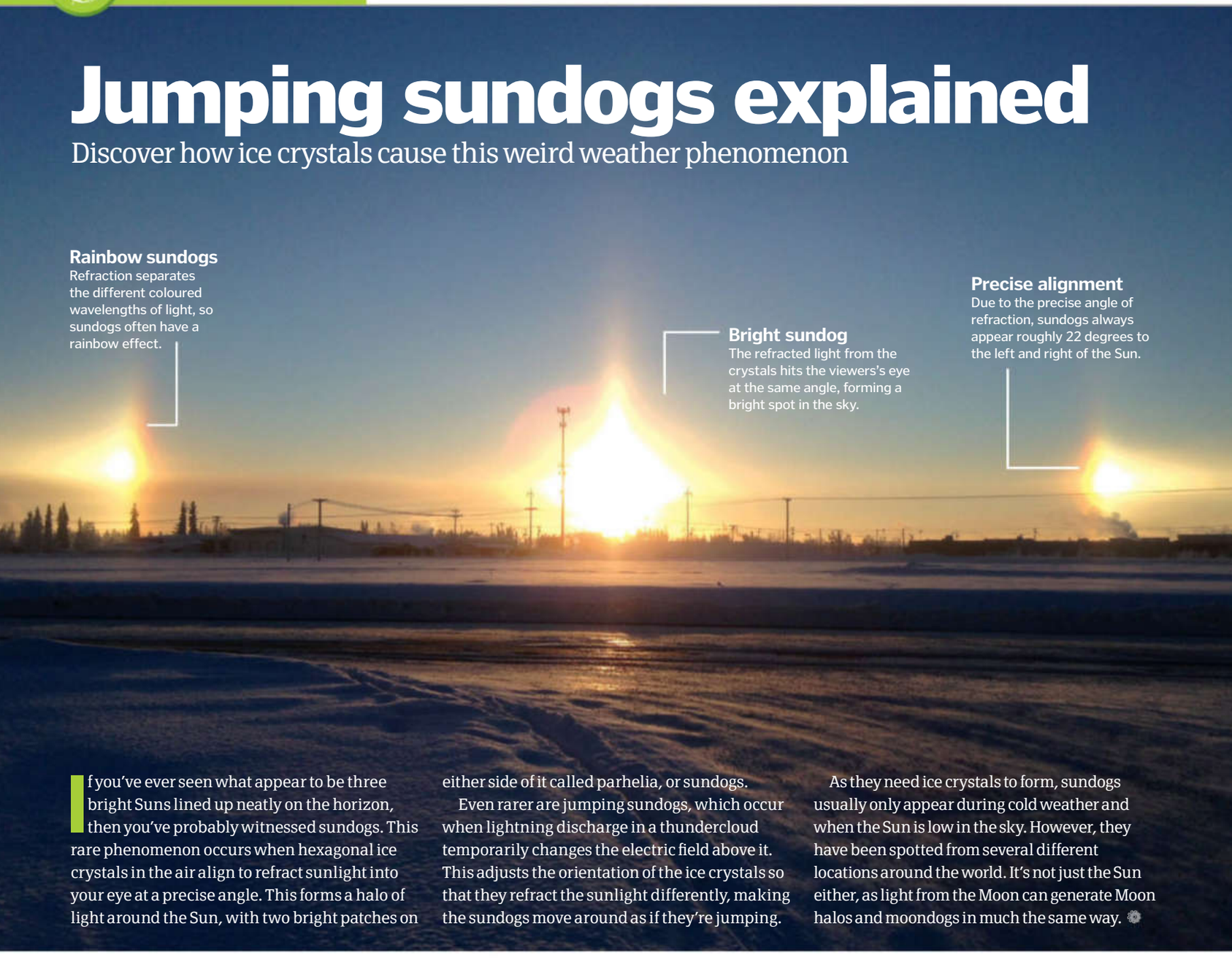
The large animals are just tiny cogs in the giant wheel that keeps the savannah biome in balance. Of equal importance are the smaller creatures and tiny insects that work the savannah soil and decompose the waste to recycle nutrients.

Humans also flourish on these grasslands. Tribes such as the Maasai have lived and farmed there for many years, as the soil facilitates the growth of cereal crops and the grazing of cattle. While we worry about garden invaders like foxes, the Maasai are concerned about elephants trampling and eating their produce! They are a culture steeped in tradition and have a strong bond with the land.

©Sol 90: Bjørn Christian Tørrissen; Etosha National Park, Namibia

Jumping sundogs explained

Discover how ice crystals cause this weird weather phenomenon



If you've ever seen what appear to be three bright Suns lined up neatly on the horizon, then you've probably witnessed sundogs. This rare phenomenon occurs when hexagonal ice crystals in the air align to refract sunlight into your eye at a precise angle. This forms a halo of light around the Sun, with two bright patches on either side of it called parhelia, or sundogs.

Even rarer are jumping sundogs, which occur when lightning discharge in a thundercloud temporarily changes the electric field above it. This adjusts the orientation of the ice crystals so that they refract the sunlight differently, making the sundogs move around as if they're jumping.

As they need ice crystals to form, sundogs usually only appear during cold weather and when the Sun is low in the sky. However, they have been spotted from several different locations around the world. It's not just the Sun either, as light from the Moon can generate Moon halos and moondogs in much the same way.

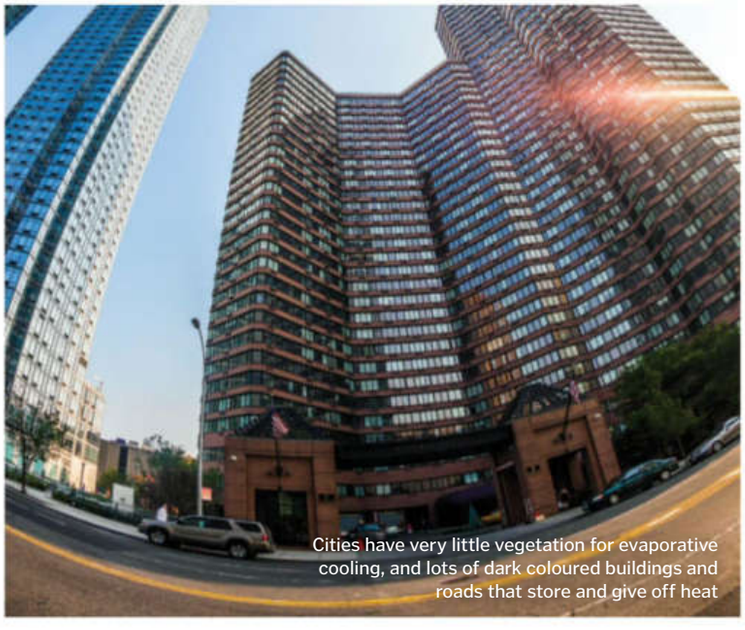
Why cities are hotter than the countryside

The effect that causes rising urban temperatures

It's not just busy public transport that makes city life feel sweatier than rural areas. On average, densely populated cities are one to three degrees Celsius (1.8 to 5.4 degrees Fahrenheit) warmer than their surroundings, resulting in a phenomenon known as the urban heat island effect.

Dark surfaces of urban buildings and asphalt roads absorb lots of sunlight during the day. The stored energy is given off as heat, warming the area by as much as 12 degrees Celsius (22 degrees Fahrenheit). Another contributing factor is that cities have less vegetation than the countryside, meaning plants can't help to cool the air by using the excess heat to evaporate the water they absorb.

Use of cars and air conditioning also increases temperatures in urban areas.



Cities have very little vegetation for evaporative cooling, and lots of dark coloured buildings and roads that store and give off heat

Nest building

Learn how weaver birds knit and tie knots to build amazing structures

Not content with simply gathering a few twigs to fashion an open-top nest, weaver birds go to a lot more effort to create a home for their young. Their enclosed and intricately woven creations not only help to keep out predators, but are also used to attract prospective mate.

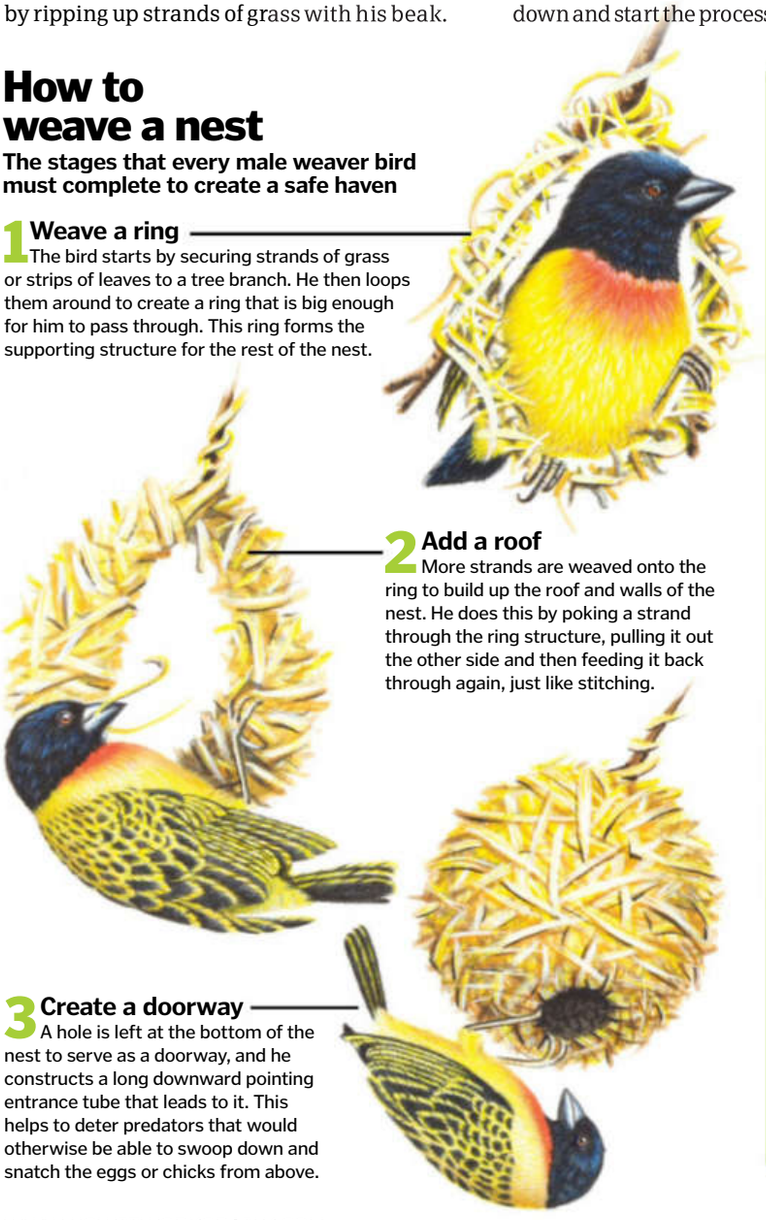
It's the male weaver birds that do the building, and the females judge who they want to mate with based on his construction skills. Therefore, it is vitally important that the structure is strong and secure. The male bird begins the process by finding a bare tree branch, and then gathers his building materials by ripping up strands of grass with his beak. Over 1,000 blades of grass are needed to make one nest, so a great deal of energy is required to harvest them one at a time. Only the freshest and most supple strands will do, as he needs to be able to fix them to the branch using complicated knots and stitches similar to the actions of a human weaver.

Using his thin beak as the needle, he weaves a neat lattice-like pattern, alternately threading strands above and below the strands that run perpendicular to it, to create an incredibly strong structure. However, once the grass dries out and turns brown, the female will consider it too weak and unfit for her young, meaning he has to cut it down and start the process all over again.

Male weaver birds build nests to attract potential mates

How to weave a nest

The stages that every male weaver bird must complete to create a safe haven



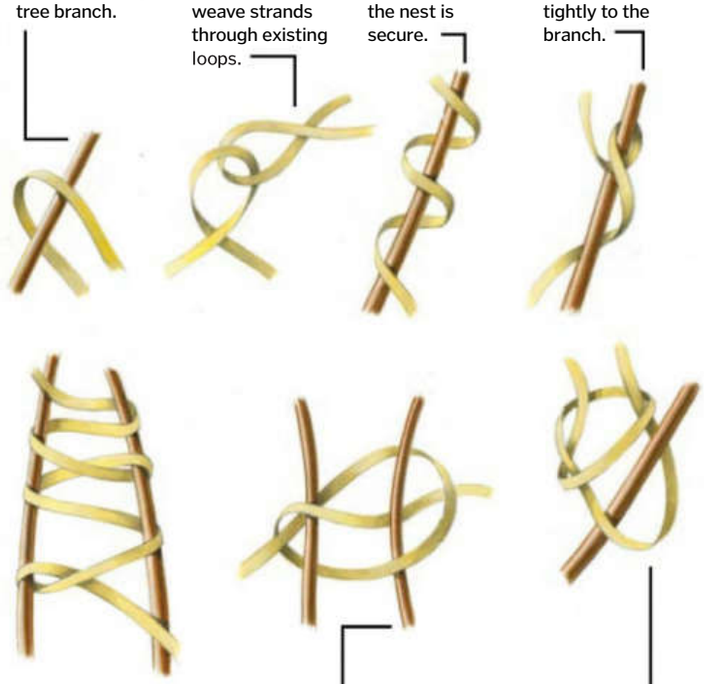
1 Weave a ring
The bird starts by securing strands of grass or strips of leaves to a tree branch. He then loops them around to create a ring that is big enough for him to pass through. This ring forms the supporting structure for the rest of the nest.

2 Add a roof
More strands are weaved onto the ring to build up the roof and walls of the nest. He does this by poking a strand through the ring structure, pulling it out the other side and then feeding it back through again, just like stitching.

3 Create a doorway
A hole is left at the bottom of the nest to serve as a doorway, and he constructs a long downward pointing entrance tube that leads to it. This helps to deter predators that would otherwise be able to swoop down and snatch the eggs or chicks from above.

Types of stitches

Some of the intricate techniques weaver birds use to build a nest



Simple loop
The very first step to building a nest involves looping a strand around a strong tree branch.

Interlocking loops
To fashion a rope that serves as the foundation of the nest, the birds weave strands through existing loops.

Spiral coil
The birds may loop the initial strand around a branch several times to ensure the nest is secure.

Half hitch
Once the first simple loop is formed, the birds use a half hitch stitch to secure it tightly to the branch.

Alternately reversed winding
To strengthen the foundation of the nest, the birds may weave the initial strand between two branches.

Overhand knot
The birds can loop a strand and feed the end back through to secure it to branches or other strands.

Slip knot
Weaver birds can use complicated slip knots to weave strands and branches together to form their nests.

SPACE TOURISM

Will we really be able to book a package holiday to space in the coming years?

Following the popularity and success of NASA's manned Apollo missions in the late 1960s, it seemed that space tourism would soon become a reality. Pan American Airways were quick to jump on the idea, opening a waiting list for a planned service to the Moon. Up until the company eventually disbanded in 1991, more than 93,000 wannabe astronauts had signed up for the scheme.

A new kind of space race was envisaged; private companies would compete to become the first to provide normal people with the chance to experience the wonders of space travel. It's incredible to think that in the years that followed Neil Armstrong's giant leap for mankind, only seven space tourists have made the trip to low-Earth orbit, none of which have even come close to retracing his famous footsteps on the lunar surface.

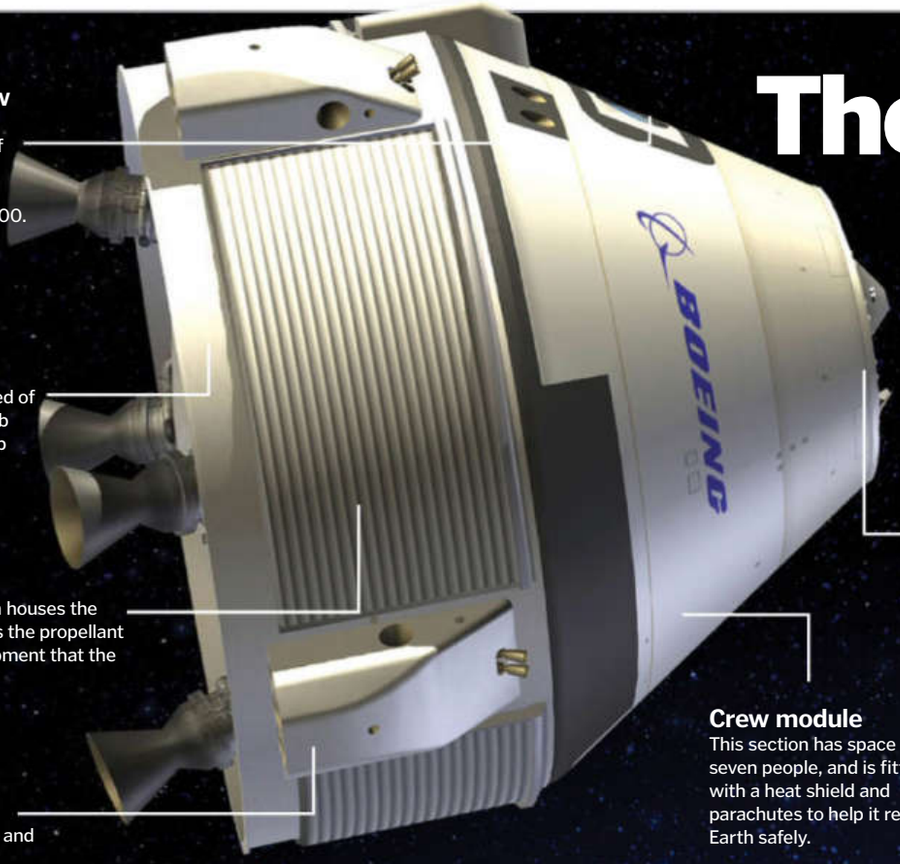
These individuals stayed on the International Space Station (ISS), and paid a considerable premium for the experience. The most recent, Canadian Guy Laliberté, coughed up an estimated £22 million ($35 million) for an 11-day trip in 2009. Although excursions to the ISS are hugely appealing, it is not designed to accommodate a tourist's needs. In spite of the ticket price, there are no luxuries; the ISS' sole purpose is to carry out vital research and support the astronauts on board.

All the space tourists used a version of the Russian Soyuz spacecraft to get to and from the ISS, but after the ISS' permanent crew was doubled to six members, this was no longer an option. This has galvanised a number of companies to explore alternative means of transporting paying passengers for short periods of time, such as space planes. The most talked-about space plane around is Virgin Galactic's SpaceShipTwo, which is lifted into the sky by a larger mothership, WhiteKnightTwo, before detaching and using its rocket engine to take a total of six passengers into space.

Once out of Earth's atmosphere, those on board will experience around five minutes of ▶

The Boeing CST-100

Designed to carry crew and cargo to the ISS, the CST-100 could also transport space tourists



Forward window
This window enables restricted views out of the spacecraft, and is one of only three windows on the CST-100.

Cost effective design
The outer layer of the spacecraft is composed of a weldless, honeycomb structure, helping keep weight and costs low.

Service module
The large back section houses the rocket engines, carries the propellant and stores other equipment that the spacecraft may need.

Reusable vessel
The CST-100 remains sturdy under pressure and can be used for a maximum of ten journeys before it needs to be replaced, keeping costs to a minimum.

Autonomous docking system
Created for docking with the ISS or a potential future space station, the forward docking system is completely autonomous, reducing training time for potential crews.

Crew module
This section has space for seven people, and is fitted with a heat shield and parachutes to help it return to Earth safely.

Wi-Fi capability
The crew's communication system will feature tablet interfaces and wireless internet.

Orbit	Launch vehicle	Height	Capsule diameter	First manned flight
Low-Earth orbit	Atlas V rocket	5.03m (16.5ft)	4.57m (15ft)	2017

SpaceX Dragon

First launch
2010

Three configurations
Cargo, crew and 'Dragon Lab'

Crew
Up to seven

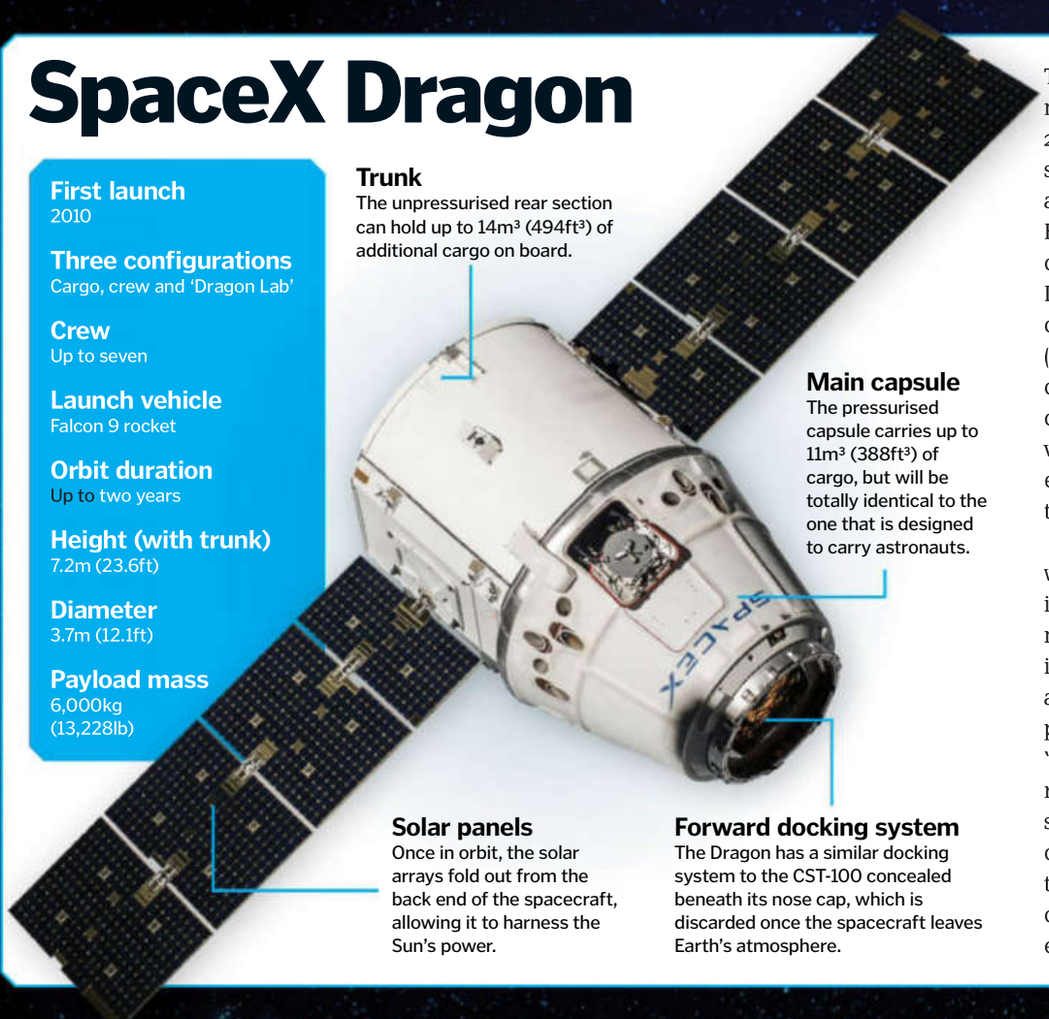
Launch vehicle
Falcon 9 rocket

Orbit duration
Up to two years

Height (with trunk)
7.2m (23.6ft)

Diameter
3.7m (12.1ft)

Payload mass
6,000kg (13,228lb)



Trunk
The unpressurised rear section can hold up to 14m³ (494ft³) of additional cargo on board.

Main capsule
The pressurised capsule carries up to 11m³ (388ft³) of cargo, but will be totally identical to the one that is designed to carry astronauts.

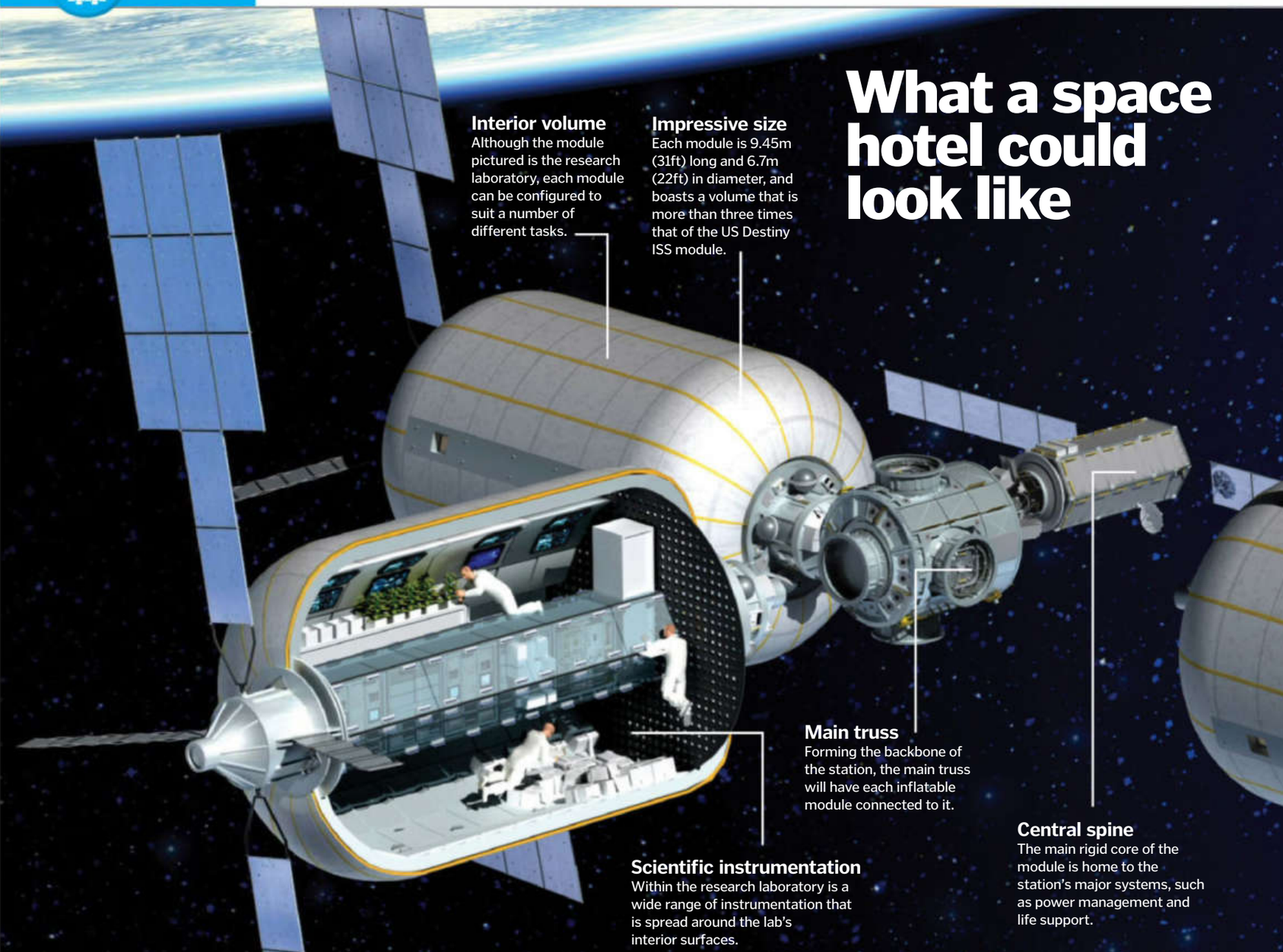
Solar panels
Once in orbit, the solar arrays fold out from the back end of the spacecraft, allowing it to harness the Sun's power.

Forward docking system
The Dragon has a similar docking system to the CST-100 concealed beneath its nose cap, which is discarded once the spacecraft leaves Earth's atmosphere.

The SpaceX Dragon has succeeded where many of its contemporaries have failed. In 2010 it became the first privately operated spacecraft to enter orbit, and was recovered after its record-breaking maiden voyage. Furthermore, the Dragon became the first commercial spacecraft to attach to the ISS. Due to this success, SpaceX signed a contract with NASA worth over £1 billion ($1.6 billion), representing a minimum of 12 cargo delivery flights to the ISS. SpaceX are currently developing the crew-carrying variant, the Dragon V2, which could eventually take both astronauts and tourists into orbit and beyond.

The first six unmanned runs to the ISS were a success. The seventh, which took off in June 2015, crashed back to Earth two minutes into the flight. After an investigation of the event, it is believed that a flawed steel strut that held a helium pressurisation bottle failed, resulting in an 'overpressure event' that destroyed the rocket. Where this leaves SpaceX is hard to say; they are still one of only a few companies to complete a space mission, yet this recent mishap may damage their chances of becoming the first private enterprise to partake in space tourism.

What a space hotel could look like



weightlessness, while gazing in wonder at the Earth's curvature and the surrounding stars. The tragic death of pilot Michael Alsbury during a test flight in 2014 has not deterred Virgin Galactic from reaching their goal, although it has meant that the first commercial flights have been further delayed. Whether or not this will form the foundation of space tourism is yet to be seen, but they do not offer a prolonged off-world stay. They also lack docking capabilities, which means they can't be used to whisk people away to any form of space hotel that may exist one day.

Aerospace company Boeing has taken a different tact. They have created a spacecraft that is likely to perform the first commercial flights, as part of a £2.7 billion ($4.2 billion) contract with NASA. The Crew Space Transportation-100, or CST-100 for short, has been tasked with this honour. Boeing and NASA hope that this spacecraft's first manned flight will take place in 2017, and once this has been completed, along with service flights to the ISS, the door will be open for commercial spaceflight.

The CST-100 is slightly larger than the Apollo Command Module and is being developed in cooperation with Bigelow Aerospace, as the capsule offers a means of reaching their planned space station in the future. As it is reusable, Boeing's spacecraft will be fitted with a combined recovery system featuring both parachutes and airbags, allowing it to land on the ground rather than in water when it returns to Earth. Reusability is key to its success, as the more times it can be used, the cheaper each flight will become for both the company and prospective customers.

If the future of space tourism doesn't involve staying on the ISS, there needs to be a new form of space station, which is where Bigelow Aerospace comes in. Their founder Robert Bigelow made his

"Despite having many of the necessary components in place, we are still a number of years away from space tourism taking off"

In-orbit assembly
The inflatable design does provide a large useable volume, but can be enlarged further by the addition of extra modules in space.

Docking ports
Each module has connectors at both ends, which function to provide docking points for different spacecraft and help join the station together.

Both of these products took their inspiration from NASA astronaut Donald Pettit, who tried to design a cup while in space

Life in space

In spite of the many trials and tribulations it has experienced, space tourism is certainly going to happen. A number of companies have recognised the need for specific products in space; ones that are capable of overcoming the issues of microgravity.

One such company is the Cosmic Lifestyle Corporation, which has already designed a zero-gravity cocktail glass and coffee cup. Each glass is designed with a specific set of grooves that channel the liquid towards the mouthpiece. Without these grooves, the liquid would float out of the glass in sticky blobs which can scatter uncontrollably.

A space currency to pay for your Martinis may not yet exist, but as of 2014 there has been a way to pay for things in orbit. PayPal Galactic enables cashless payments to be carried out in space, and will even be capable of sending money back to Earth and vice versa. Although the cocktail glass isn't essential to our way of life, its technology will no doubt be seen more and more when space tourism takes off.

fortune building hotels, but he has been interested in space technology since childhood. Taking inspiration from NASA's 'TransHab' concept, Bigelow Aerospace plans to build its own inflatable space modules. It will use these to build private space stations, which it will operate and sell access to the public.

In 2006 and 2007, Bigelow launched Genesis 1 and 2 respectively, which were its first test craft to enter orbit. Since these launches the company has been relatively quiet, relying on ground testing while waiting for space tourism to grow as an industry. However, the BEAM (Bigelow Expandable Activity Module) is scheduled to launch later this year aboard a SpaceX Dragon capsule, and it will be connected to the ISS for two years to demonstrate its technology. Once this has been proven a success, the B330 will be launched. This has over 20 times the volume of the BEAM with 330 cubic metres (11,654 cubic feet) of internal space, and a proposed 20-year lifetime. Although its walls are inflatable, they will provide inhabitants with more protection from heat and radiation than the rigid ISS modules. Bigelow hopes that these modules will mark the beginning of vacations that truly are out of this world.

However, despite having many of the necessary components in place, we are still a number of years away from space tourism becoming a truly viable vacation option. It's more likely that trips to low-Earth orbit will become well-established first, before any form of 'hotel' opens for business. There is still so much that needs to be investigated before space travel can become feasible for the average person. Further research into the effects of remaining in space for long periods of time is vital, and it's hoped that NASA's ongoing Twins Study will provide some answers.

What is certain is that there will be plenty of adventurers packing their bags for a trip to infinity and beyond when the time comes.

Extreme cosmic temperatures

What are the hottest and coldest temperatures in space, and where can we find them?

Absolute zero

-273.15°C (-459.67°F)

The lowest temperature possible, zero degrees Kelvin.

Elements | Space tech | Earth | Solar System | Milky Way | Universe

Celsius: -250, -200, -150, -100, -50, -40, 0°, 32

Fahrenheit: -400, -328, -200, -148, -40, 0°

-272.2°C/-457.96°F

Lowest freezing point

Helium will remain liquid right down to near absolute zero.

450 picokelvin

Coldest recorded temperature

A team of scientists from MIT cooled sodium gas to a fraction above absolute zero.

-240°C/-400°F

Lunar craters

The Moon is cold enough anyway, but there are craters on its surface in permanent shadow that never rise above this temperature.

-272°C/-458°F

Deep space refrigerator

The Boomerang nebula 5,000 light years from Earth, is the coldest natural place in space.

Pluto's icy heart

From a distance of 450,000 kilometres (280,000 miles) away, New Horizons' Long Range Reconnaissance Imager (LORRI) took four photos to create this composite colour image of Pluto, revealing some curious details. The heart-shaped Tombaugh region (named after the astronomer who discovered Pluto in 1930) is split into two lobes in this image, and it's thought that temperatures as low as -223 degrees Celsius (-369 degrees Fahrenheit) cause nitrogen to precipitate as snow and flow from one side of the region to the next in massive glaciers. The team at New Horizons mission control also think that this vast area acts as a kind of reservoir that feeds both its geological and atmospheric activity.

-93.2°C/-135.8°F

Coldest place on Earth

This was measured in eastern Antarctica by a NASA satellite, so is not an official Guinness world record.

-40°C/-40°F

Equilibrium

The point at which both the Celsius and Fahrenheit scales have the same value.

-38.83°C/-37.89°F

Mercury freezes

Your thermometer will be useless in the depths of an Antarctic winter.

-48°C/-54°F

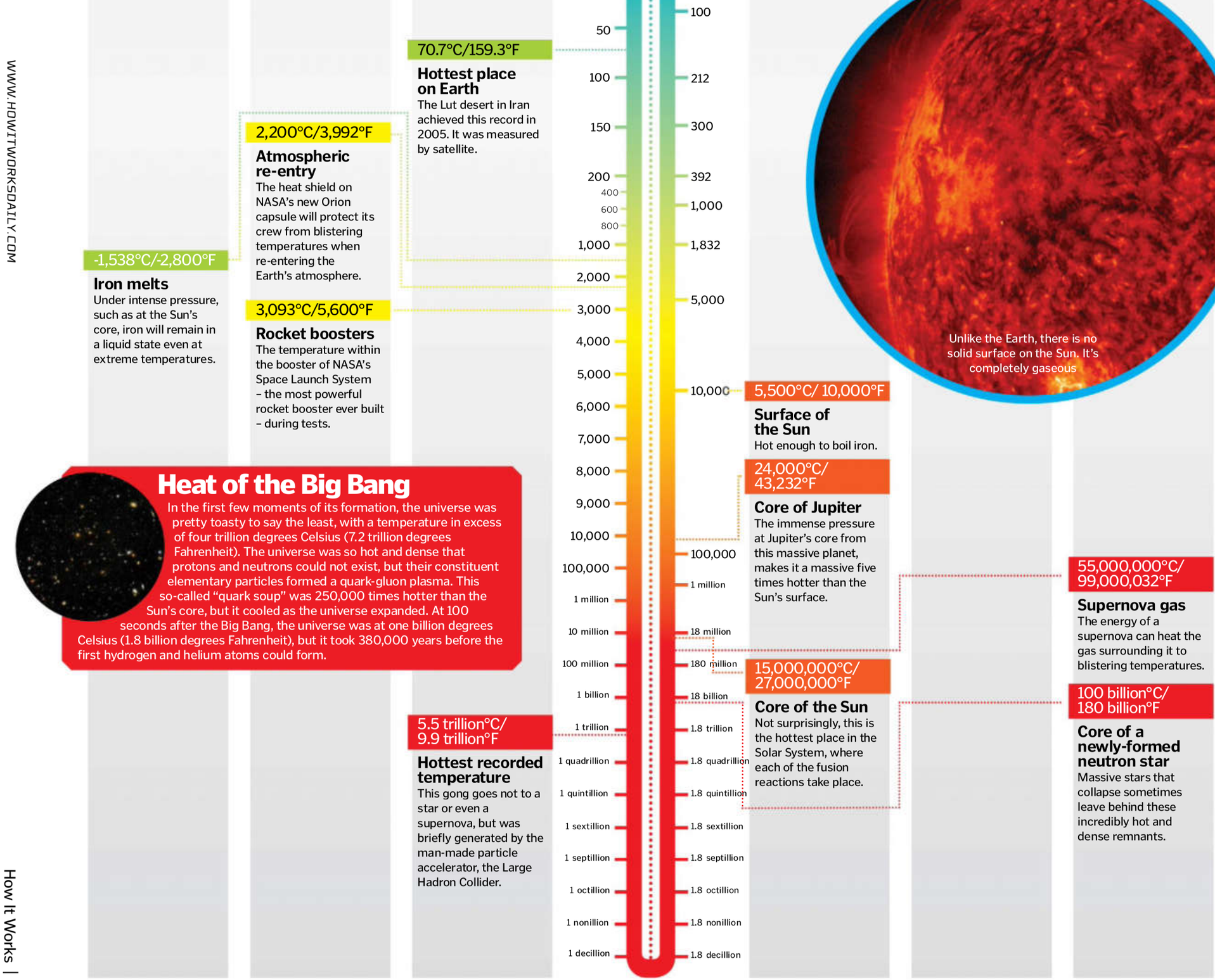
Coldest brown dwarf star

Sub-stellar objects can achieve surprisingly low temperatures, including this record-breaking neighbour of ours that is just 7.2 light years away.

0°

0°

DID YOU KNOW? *In 2013, physicists created a method of forcing a quantum gas to reach temperatures below absolute zero*



Planck temperature

142,000,000,000,000,000,000,000,000,000,000°C (255,000,000,000,000,000,000,000,000,000,000°F)

The hottest (theoretical) temperature of matter achievable.

Blowing up asteroids

How NASA plans to save us from killer space rocks

It was 66 million years ago that the dinosaurs' reign on Earth came to an end. The instigator was an asteroid, a large lump of space rock of around ten kilometres (six miles) in diameter, which struck the Earth with a force that's one billion times greater than the Hiroshima bomb. Today, the destruction is evident in the form of the Chicxulub impact crater in Mexico, approximately 20 kilometres (12 miles) deep, by 180 kilometres (112 miles) wide.

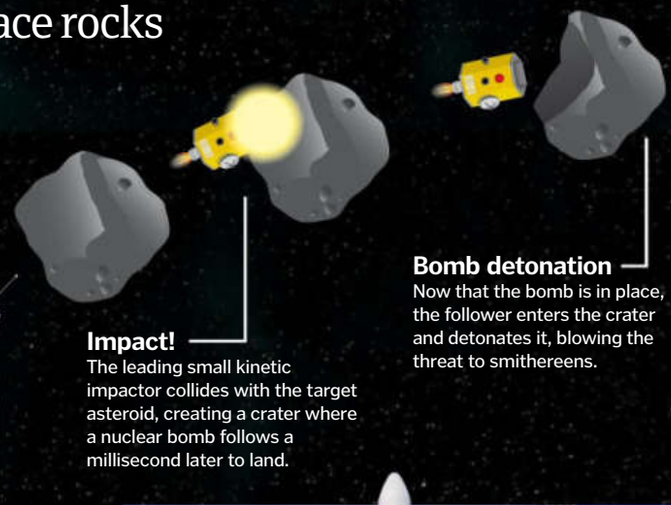
With asteroids tumbling through the Solar System and some coming close to our planet, it's only a matter of time until we end up with the same fate as the dinosaurs. That's why we have to act fast in getting rid of a potentially hazardous asteroid before it gets to us. The solution? NASA's Hypervelocity Asteroid Intercept Vehicle, or HAIV for short, which works by blasting an Earth-bound chunk of rock to smithereens with the help of a nuclear bomb.

HAIV will be coupled with an asteroid warning system – even if there's less than a week until we're hit by an asteroid, HAIV can still be used, meaning that it's never too late to protect our planet. The spacecraft will be launched to rendezvous with the target asteroid. It will then use an impactor to carve out a crater and, only a millisecond behind, a bomb follows to fit inside the pre-drilled hole. The bomb then detonates, shattering the asteroid into millions of tiny pieces.

Depending on how close the devastated asteroid is to Earth, it's thought that the fragments could still hit our planet in the form of an intense meteor shower. However, provided that the fragments were small enough, we would be largely unaffected as they would burn up in our atmosphere

The asteroid destroyer's flight plan

The HAIV undergoes a series of manoeuvres before it destroys its quarry



Bomb detonation
Now that the bomb is in place, the follower enters the crater and detonates it, blowing the threat to smithereens.

Impact!
The leading small kinetic impactor collides with the target asteroid, creating a crater where a nuclear bomb follows a millisecond later to land.

Ready to crash
Before it reaches the asteroid, the leader portion of the spacecraft needs to separate itself from the follower.

A continual stream
Once the HAIV has located the asteroid, the camera provides a continual stream of images of the target in case any correction manoeuvres are needed.

Sniffing out the threat
Now in space, the spacecraft seeks out the asteroid threat using its highly sensitive sensors and optical/infrared cameras.

Follower and leader
The spacecraft is made up of two parts – the leader and the follower. The leader holds the instruments such as the camera, while the follower is the back-end of the spacecraft.

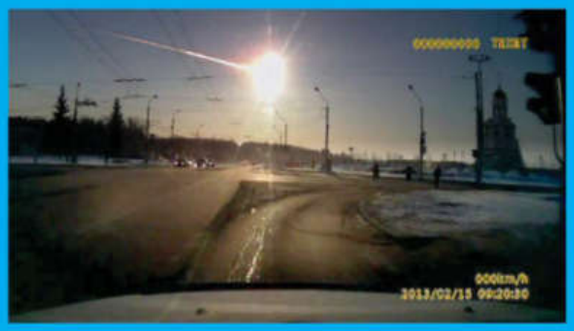
Ready for launch
When an asteroid is on its collision path with Earth, the Hypervelocity Asteroid Intercept Vehicle is launched on a rocket.

NASA's Hypervelocity Asteroid Intercept Vehicle would be launched on a high-capacity rocket such as a Delta IV Heavy

The wake-up call

It was the fireball that exploded over Chelyabinsk in Russia on the morning of 15 February 2013, that further highlighted the need for an asteroid protection program, which includes the likes of the Hypervelocity Asteroid Intercept Vehicle.

With some eyewitnesses claiming that they felt intense heat from the meteor, which was brighter than the Sun and had 20 to 30 times more energy than that released by the Hiroshima bomb when it exploded, the lump of space debris injured around 1,500 people and damaged over 7,000 buildings. Small fragmentary meteorites that survived the blast were found later, along with a six-metre (20-foot) wide hole on Lake Chebarkul's frozen surface.



Several drivers' dashboard cameras recorded the fireball

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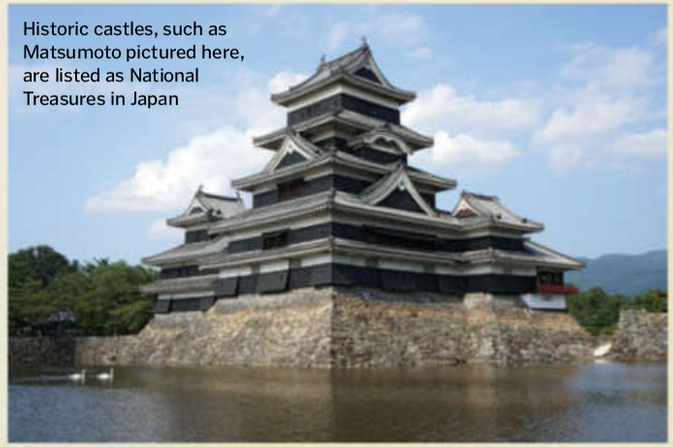
Life inside a Japanese castle

Whether at peace or at war, life was hard for the population it protected

A medieval Japanese castle was not only the geographical centre of a ruler's territory; it was also their most important structure. The population relied on the castle to defend them when war began; during times of peace they would either work to maintain the castle, grow food for its army or fight for it in distant campaigns.

Extremely strict rules were enforced on the locals; if a man was away fighting a campaign, his wife would be forced to make repairs to the castle if it was damaged by the weather. The daimyo's (ruler's) needs were always the priority. If a single person failed to complete their task, a punishment would be imposed on the entire company.

When war began, the daily lives of both the garrison and the general population drastically changed, as the castle was quickly converted into an active military headquarters. All available personnel would immediately be tasked with fortifying the castle, typically by either replastering the castle walls, constructing extra palisades (defensive fences of wooden stakes) or by deepening the ditch that surrounded the castle's walls. If the battle was lost, everyone inside the castle was at risk of execution.



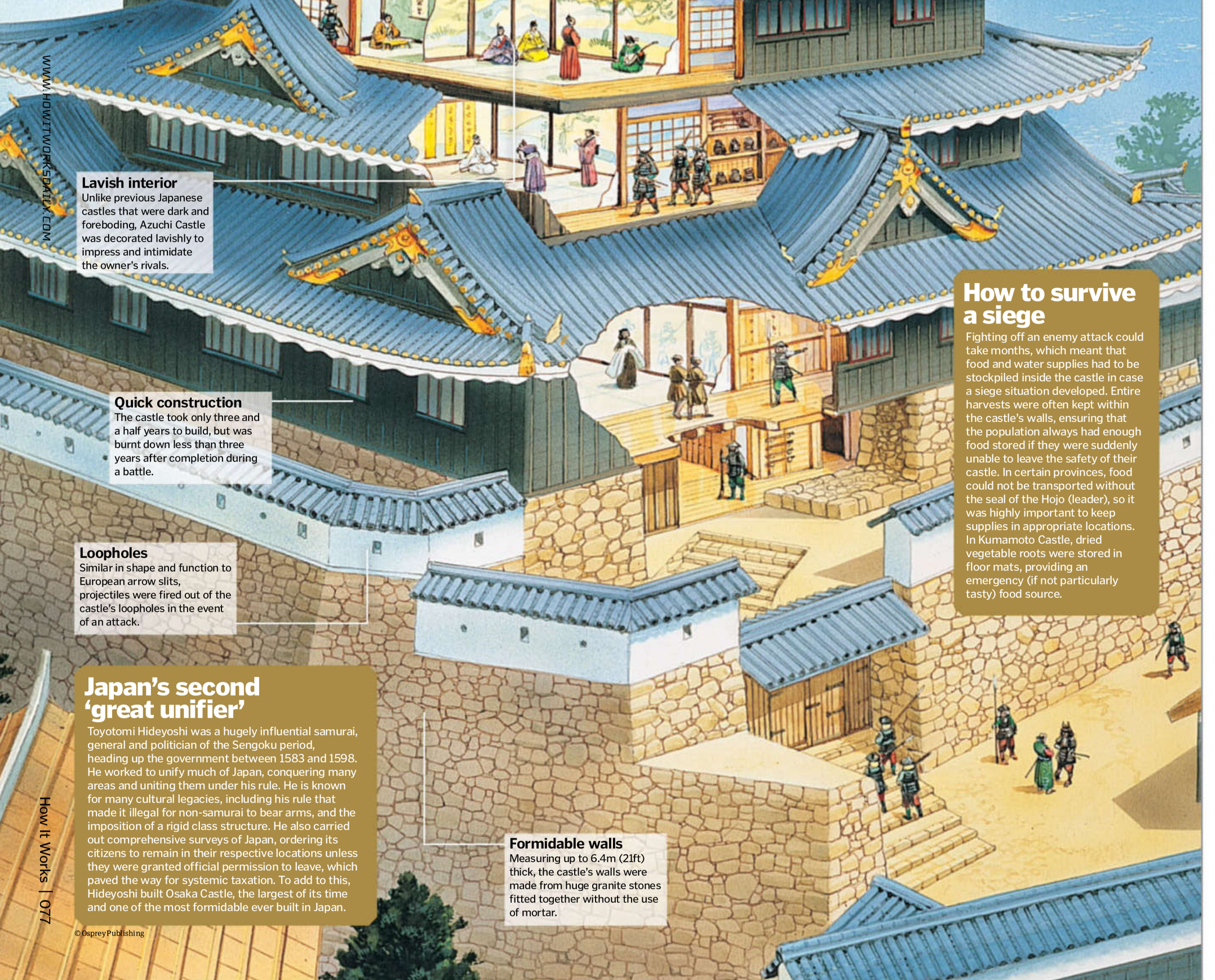
Historic castles, such as Matsumoto pictured here, are listed as National Treasures in Japan

Hip roof
This type of roof design is known as irimoya, and features a hip and gable structure. The sides of the roof slope down and then turn up slightly.

Novel location
Azuchi Castle was built at a great height to give a wide view of an approaching enemy, whereas most Japanese castles were built at the base of a mountain surrounded by dense vegetation.

Main keep
Azuchi Castle's main keep was an impressive seven stories high, and is thought to have been the largest wooden building in the world when it was built.

Gable
Decorative gables are thought to have been a prominent feature of the design on the outer castle, and were more elaborate than its contemporaries.



Lavish interior
Unlike previous Japanese castles that were dark and foreboding, Azuchi Castle was decorated lavishly to impress and intimidate the owner's rivals.

Quick construction
The castle took only three and a half years to build, but was burnt down less than three years after completion during a battle.

Loopholes
Similar in shape and function to European arrow slits, projectiles were fired out of the castle's loopholes in the event of an attack.

Formidable walls
Measuring up to 6.4m (21ft) thick, the castle's walls were made from huge granite stones fitted together without the use of mortar.

How to survive a siege

Fighting off an enemy attack could take months, which meant that food and water supplies had to be stockpiled inside the castle in case a siege situation developed. Entire harvests were often kept within the castle's walls, ensuring that the population always had enough food stored if they were suddenly unable to leave the safety of their castle. In certain provinces, food could not be transported without the seal of the Hojo (leader), so it was highly important to keep supplies in appropriate locations. In Kumamoto Castle, dried vegetable roots were stored in floor mats, providing an emergency (if not particularly tasty) food source.

Japan's second 'great unifier'

Toyotomi Hideyoshi was a hugely influential samurai, general and politician of the Sengoku period, heading up the government between 1583 and 1598. He worked to unify much of Japan, conquering many areas and uniting them under his rule. He is known for many cultural legacies, including his rule that made it illegal for non-samurai to bear arms, and the imposition of a rigid class structure. He also carried out comprehensive surveys of Japan, ordering its citizens to remain in their respective locations unless they were granted official permission to leave, which paved the way for systemic taxation. To add to this, Hideyoshi built Osaka Castle, the largest of its time and one of the most formidable ever built in Japan.

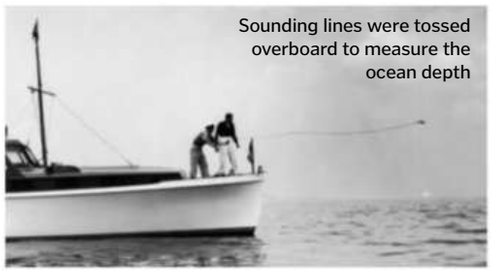
DID YOU KNOW? *To protect a Japanese castle's wooden walls from enemy fire attacks, they were coated with fireproof plaster*

How did we measure ocean depth?

Explore the clever methods used to take the first measurements of the sea floor

The first evidence of humans attempting to measure the depth of the oceans has been found in Egyptian tomb paintings from 1800 BCE. The images show a man on a boat dipping a sounding pole (a long rod used to measure depths) into the water and measuring how far it goes in before it reaches the bottom. This technique didn't change much for the next several thousand years, with the pole simply switched for a rope with a weight on the end.

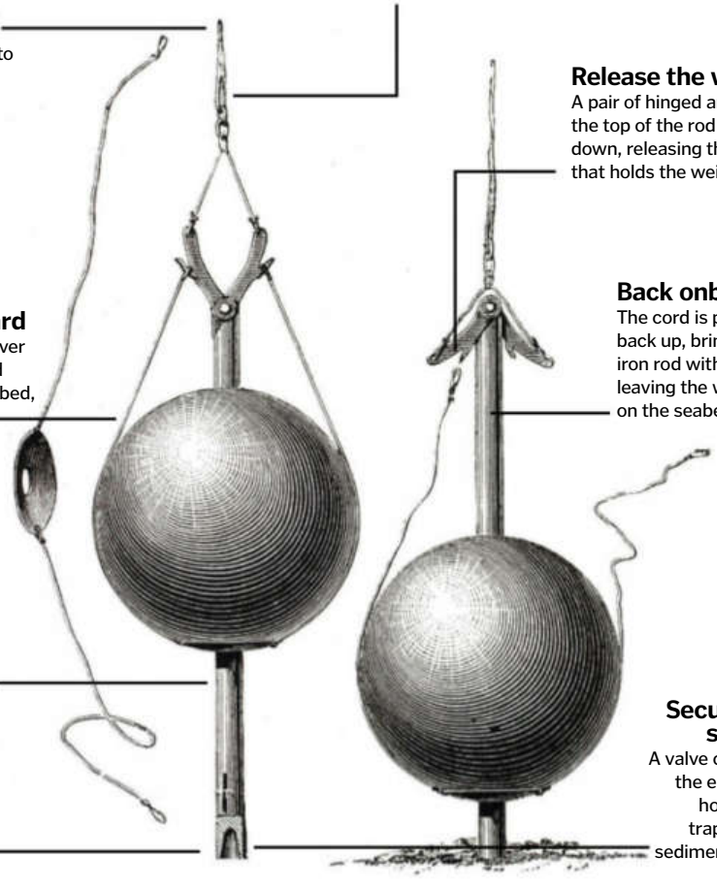
Most of the measurements were taken in shallow areas to identify near-shore hazards for shipping, but in 1872 the first wide-scale study of the world's oceans began. On its four-year expedition, the HMS Challenger took 360 depth readings of the sea floor using a variety of sounding devices. These devices used a weight to pull a sounding line to the seafloor and collected samples from the seabed in the process. The findings helped to identify underwater mountain ranges and trenches, as well as thousands of new marine species, forming the basis of modern oceanography. However, it wasn't until 1914 that sonar was first used to take more accurate measurements.



Sounding lines were tossed overboard to measure the ocean depth

The Brooke's sounding apparatus

How this deep-sea sounding device worked



Weight and cord
The weight is attached to a cord with markers spaced 25 fathoms (45.7m/150ft) apart.

Take measurements
By counting the number of markers that are pulled under the water, the approximate depth of the ocean is measured.

Release the weight
A pair of hinged arms at the top of the rod fall down, releasing the sling that holds the weight.

Lowered overboard
The weight is lowered over the side of the boat, and when it reaches the seabed, the cord goes slack.

Back onboard
The cord is pulled back up, bringing the iron rod with it, but leaving the weight on the seabed.

Into the seabed
When the weight reaches the bottom, the iron rod that passes through its centre is driven into the seabed.

Collect sediment
As the bottom end of the rod is hollow, it fills with the sediment on the ocean floor.

Secure the sample
A valve closes up the end of the hollow rod, trapping the sediment inside.

5 horrible facts about hygiene

The gruesome practices that were once considered healthy!

1 Urine mouthwash
Ammonia, a common ingredient of household cleaners, is also found in urine, and so the Romans used it to clean their clothes. However, they also believed its stain removing powers could clean and whiten teeth, and so they regularly gargled with it as mouthwash.

2 Toilet closets
In medieval houses, toilets were basically a bowl covered by a slab of wood with a hole in the middle. They could usually be found in closets called garderobes, and people would often keep their clothes in their as the smell helped to keep moths away.

3 Rotten teeth
The Tudors knew that sugar rotted their teeth, but because sugar was so expensive and therefore a sign of wealth, Tudor women would deliberately blacken their teeth to make them look rotten!

4 Hair-raising treatments
A common treatment for baldness in the 17th century was to mix potassium salts with chicken droppings and rub it into the scalp. Alternatively, one method for removing hair involved creating a paste from eggs, vinegar and cat dung.

5 Mouse-skin eyebrows
During the 18th century, it was unfashionable for women to have thick eyebrows, so they would shave them off and replace them with ones made from mouse skin. Pale make-up was also popular – but deadly – and contained poisons such as lead and mercury.

Toilets were built on the outside of medieval castles so waste would run into the moat

Anatomy of a 19th century fireman

How the USA's volunteers put the fight in firefighter

Today, firefighters are brave heroes that come to our rescue with efficiency and professionalism, but that hasn't always been the case. During the late 18th century and early 19th century, firefighters in the USA didn't have such a good reputation. Rather than being employed by the government, they were typically volunteers who had been let off military service or jury duty, and had to buy their own uniforms and equipment.

Firehouses became like social clubs and when news of a fire broke, the volunteers would race those from other fire companies to reach the scene first, dragging heavy hand-operated water pumps with them. These competitions often resulted in the firefighters battling each other instead of the fire!

Soon, local gangs began associating themselves with the firehouses, and the firefighters became involved in party politics. This resulted in even more violence, with the firefighters sometimes starting fires themselves. One particularly lethal confrontation in 1856 became known as the Know-Nothing riot, and saw several people killed at Lexington Market in Baltimore.

By the mid-19th century, insurance companies and the Republican Party were lobbying for a professional fire service and when horse-drawn, steam-powered water pumps became available, the volunteers were replaced with paid fire departments.

Helmet
The reinforced dome helmets made from specially treated leather had an angled brim so that water could run off the back.

Beard
Firefighters would soak their beards in water, bite them, then breathe through them to prevent themselves from inhaling fumes from the fire.

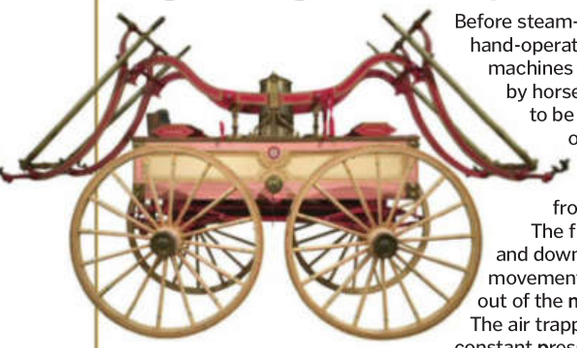
Red shirt
Bright red, bibbed shirts helped people identify the firefighters, and they soon became a symbol of elevated social status.

Speaking trumpet
Excited and noisy crowds would often come to watch the firefighters at work, so they used brass speaking trumpets to relay commands.

Hose
The leather hose had seams held together by metal rivets to stop it rupturing under the pressure of the water.

Leather boots
Knee-high leather boots were worn mainly to keep the firefighters warm and dry, rather than protect them from the flames.

Fighting fires by hand



Before steam-powered fire engines, firefighters used hand-operated pumps to douse fires with water. These machines on wheels would be pulled through the streets by horse or by the firefighters themselves. Some had to be filled by hand, with so-called 'bucket brigades' of local helpers fetching water from nearby sources, but others were equipped with a suction hose that could draw water directly from municipal hydrants.

The firefighters would then pump the long levers up and down to operate a set of pistons inside. The movement of the pistons would alternately suck water out of the main tank and force it into a separate chamber. The air trapped inside the chamber would maintain a constant pressure helping to spray the water out through a hose. It requires an exhausting 60 strokes per minute to pump the water effectively, so teams of firefighters would take turns to operate the machine for a few minutes at a time.

Vostok 6 mission

How the first woman was sent into space

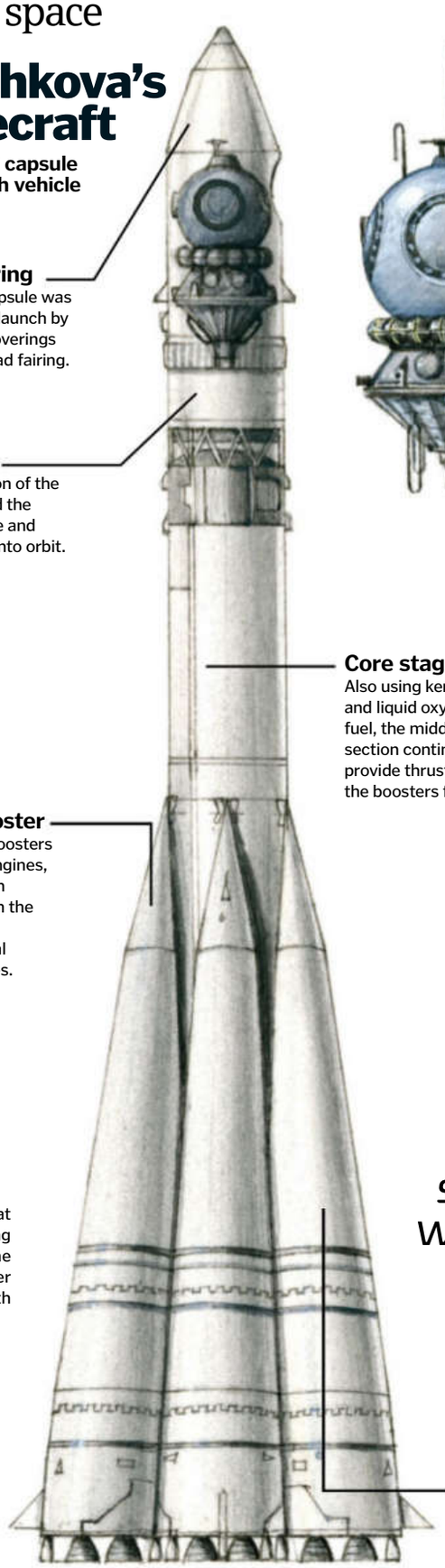
The Soviet Union achieved many firsts in the quest to explore space. They launched the first artificial satellite, Sputnik, in 1957, sent the first animal, Laika the dog, beyond Earth's atmosphere in the same year, and then launched the first human into orbit, Yuri Gagarin, four years later. However, they weren't ready to stop there, and so in 1963 they beat America to yet another space race milestone – sending the first woman into space.

Valentina Tereshkova was a textile factory worker and keen skydiver before starting cosmonaut training in 1962. She was chosen for her excellent parachuting skills, as she would be required to eject from her Vostok 6 spacecraft when returning to Earth and parachute down separately. Just one year later, at the age of 26, she was ready for her mission, uttering the words "Hey, sky! Take off your hat, I'm coming!" just before launch.

However, Tereshkova wasn't actually alone in space, as two days earlier Vostok 5 had launched onto the same orbital path. It was originally intended for both spacecraft to be piloted by women, with Tereshkova at the controls of Vostok 5, but male astronaut Valery Bykovsky ended up in the capsule. The two spacecraft came within five kilometres (three miles) of each other in orbit, and Bykovsky reported that Tereshkova hummed songs to him via radio link before they drifted apart and the connection was lost. After Bykovsky had completed 82 obits of Earth and Tereshkova had done 48, both cosmonauts successfully returned to Earth on the same day. Tereshkova was almost unconscious when she landed, but by the following day she was well enough to film a re-enactment. She soon became a global celebrity, but it would be 19 years before another woman, Svetlana Savitskaya, would follow in her footsteps.

Tereshkova's spacecraft

The Vostok 6 capsule and its launch vehicle



Vostok 6 capsule
The spherical capsule contained a 2.3m (7.5ft) wide pressurised cabin, with an ejection seat for Tereshkova to sit in.

Payload fairing
The Vostok 6 capsule was shielded during launch by two petal-like coverings called the payload fairing.

Air supply
Tanks of compressed nitrogen and oxygen provided breathable air for Tereshkova and propulsion for the spacecraft.

Final stage
The upper section of the rocket contained the Vostok 6 capsule and helped insert it into orbit.

Instrument section
The conical module underneath the capsule contained the Earth-return rocket and thermal control systems.

Core stage
Also using kerosene and liquid oxygen as fuel, the middle section continued to provide thrust when the boosters fell away.

Rocket booster
The Vostok's boosters used RD-107 engines, which had been developed from the world's first intercontinental ballistic missiles.

First stage
Each of the four boosters had a rocket engine at the base, and were fuelled by kerosene and liquid oxygen.

Learn more

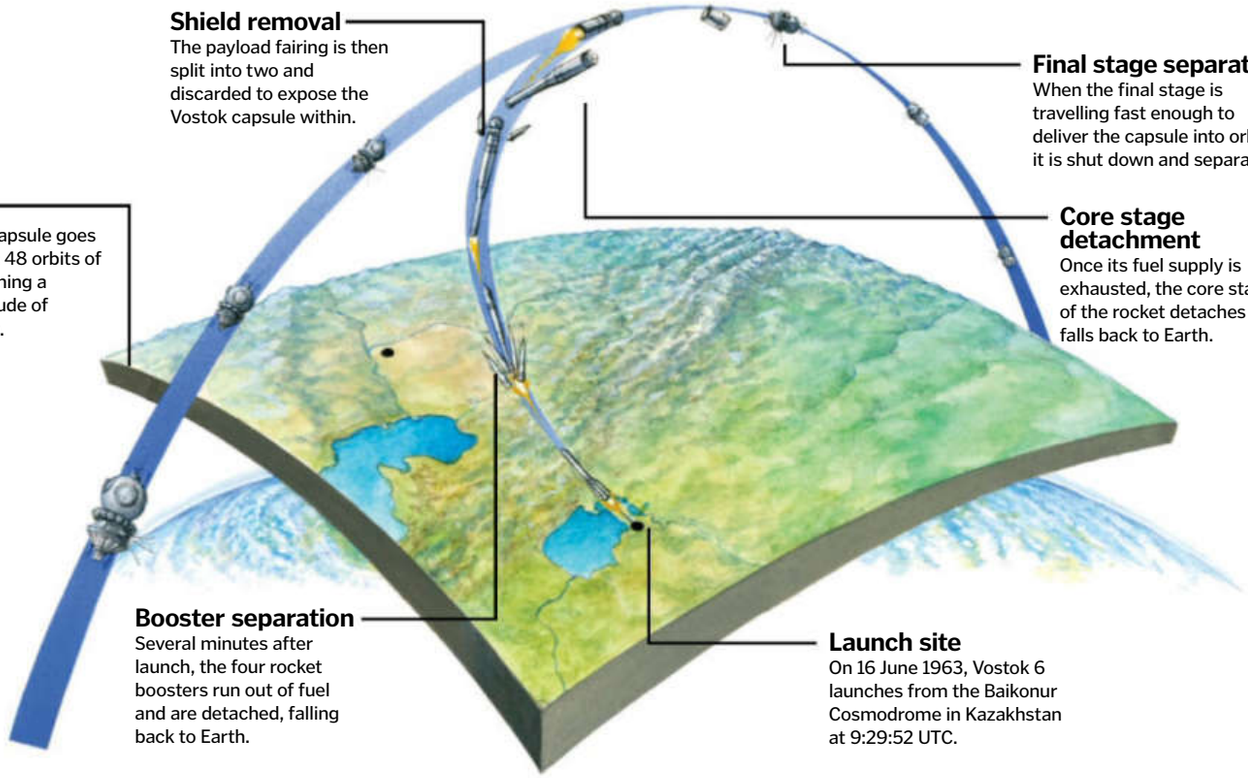
Discover more about the history of the Russian space programme by visiting the *Cosmonauts: Birth of the Space Age* exhibition at the British Science Museum, from 18 September 2015 to 13 March 2016. Tickets are available from **www.sciencemuseum.org.uk**.

"The two spacecraft came within three miles of eachother in orbit"

Much of Vostok 6's heat shield was burnt during re-entry, revealing the insulation layer beneath

Lift-off

How Vostok 6 was launched into space



Shield removal
The payload fairing is then split into two and discarded to expose the Vostok capsule within.

Final stage separation
When the final stage is travelling fast enough to deliver the capsule into orbit, it is shut down and separated.

In orbit
The Vostok 6 capsule goes on to complete 48 orbits of the Earth, reaching a maximum altitude of 231km (144mi).

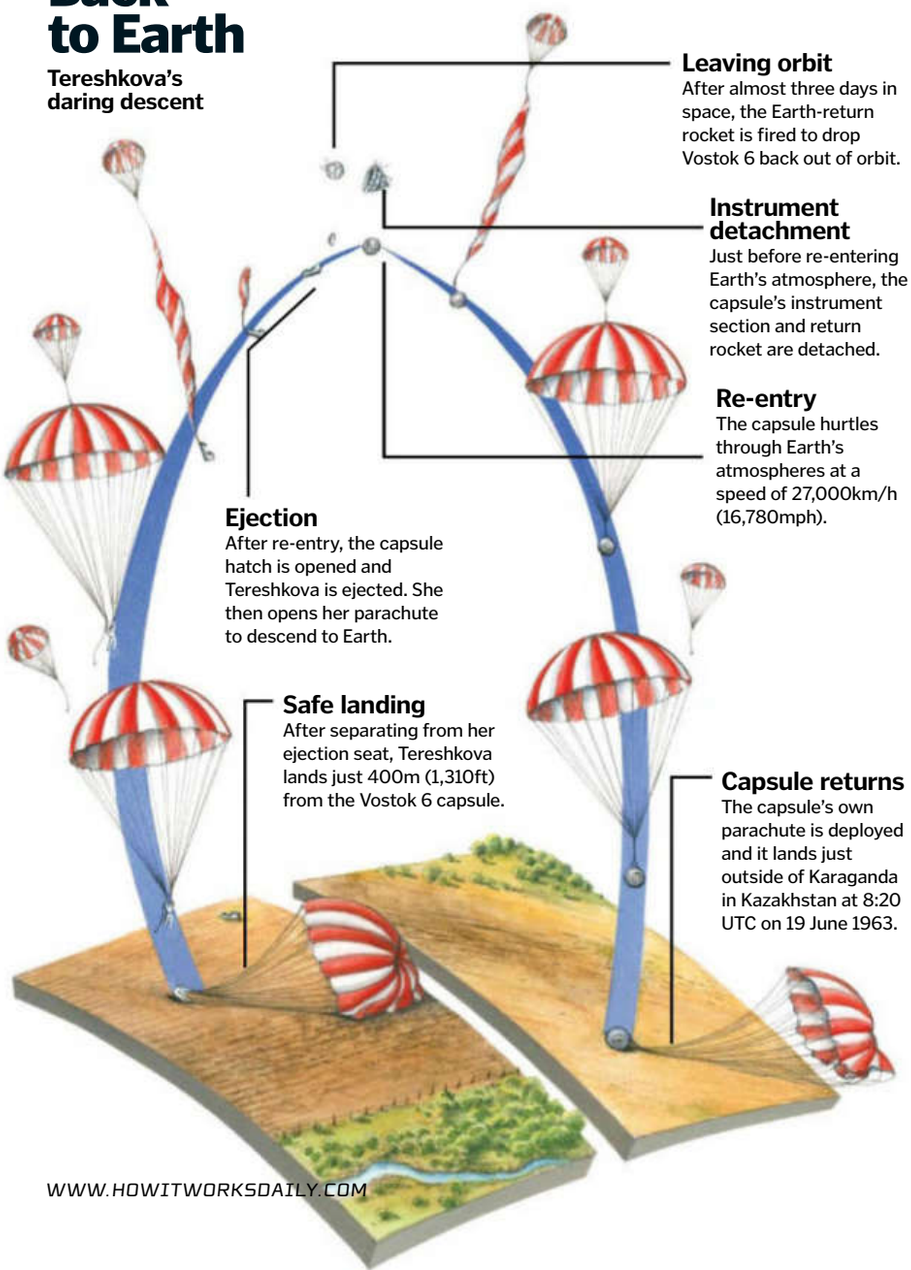
Core stage detachment
Once its fuel supply is exhausted, the core stage of the rocket detaches and falls back to Earth.

Booster separation
Several minutes after launch, the four rocket boosters run out of fuel and are detached, falling back to Earth.

Launch site
On 16 June 1963, Vostok 6 launches from the Baikonur Cosmodrome in Kazakhstan at 9:29:52 UTC.

Back to Earth

Tereshkova's daring descent



Leaving orbit
After almost three days in space, the Earth-return rocket is fired to drop Vostok 6 back out of orbit.

Instrument detachment
Just before re-entering Earth's atmosphere, the capsule's instrument section and return rocket are detached.

Re-entry
The capsule hurtles through Earth's atmospheres at a speed of 27,000km/h (16,780mph).

Ejection
After re-entry, the capsule hatch is opened and Tereshkova is ejected. She then opens her parachute to descend to Earth.

Safe landing
After separating from her ejection seat, Tereshkova lands just 400m (1,310ft) from the Vostok 6 capsule.

Capsule returns
The capsule's own parachute is deployed and it lands just outside of Karaganda in Kazakhstan at 8:20 UTC on 19 June 1963.

Tereshkova's call sign for the mission was 'Chaika', Russian for 'seagull'. She had one embroidered on her spacesuit

BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology and another in real-time computing. He's been writing about science and technology since before the web. His science-fiction novel, *A Jar Of Wasps*, is published by Anarchy Books.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

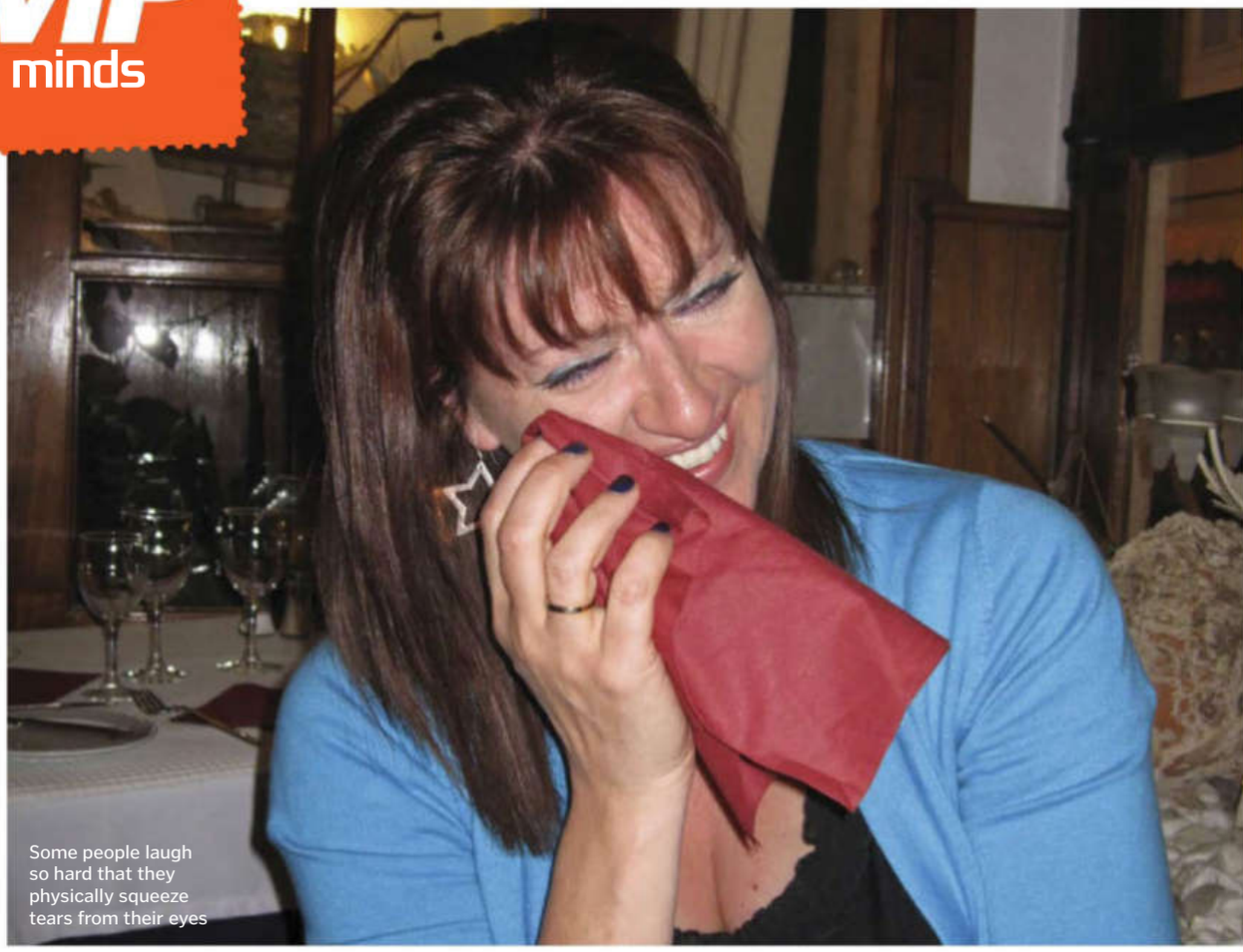
Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!



Some people laugh so hard that they physically squeeze tears from their eyes

Why do we sometimes laugh so hard, we cry?

Deborah McCubbin

■ There are two types of tears and at least two possible answers to this question. Emotional tears are, as their name suggests, produced at times of extreme emotion. The parts of the brain responsible for laughter and crying are thought to overlap, and some scientists think that this is why some people cry when they laugh.

Another explanation is that they are reflex tears. These are produced in response to environmental irritation, like when your eyes water in the wind. When you laugh really hard, muscles in your face contract and this squeezes on your tear ducts, making you cry. **LM**

Why do bees make honey?

Claudia Barns

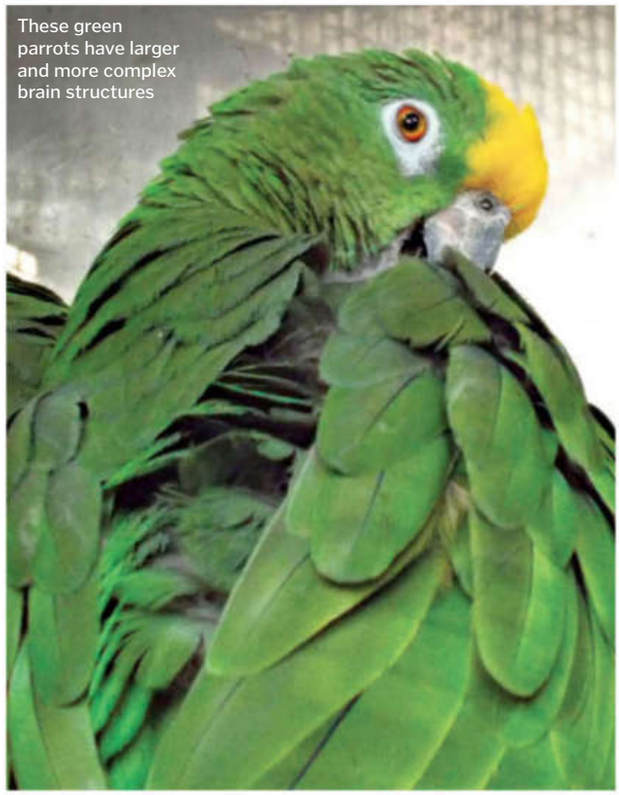
Throughout the winter months when flowers are not blooming and bees are less able to forage for food, there is little to no nectar available for them to eat. Therefore, they convert nectar into honey throughout the rest of the year to store for the hive to eat during these cold months.

Due to it being high in sugar and in turn, high in energy, honey is ideal food for these flying insects that remain active during the winter. A hive needs nine to 14 kilograms (20-30 pounds) of honey to survive an average winter, but bees are capable of collecting much more if they have the space. **SB**

How can parrots talk?

Emily Currie

■ It's important to note that parrots don't actually 'talk', meaning that they don't converse like we do; they're simply mimicking our speech. However, they're one of a very small group of animals capable of learning sounds and repeating them. Scientists had long thought that this might be due to the size of the parrots' brains, and were aware of a genetic pattern tied to vocal learning in both humans and birds that have the ability to learn songs. In June 2015, researchers at Duke University in North Carolina looked for the genetic marker in the brains of a variety of parrot species, and discovered that parrots have a unique brain structure. Along with hummingbirds and songbirds, parrots have a vocal learning centre in their brains called 'cores'. Unlike other birds with song-mimicking abilities, however, parrots also have a surrounding shell. This shell is larger in parrots that are especially known for their ability to learn and repeat human speech. **SF**

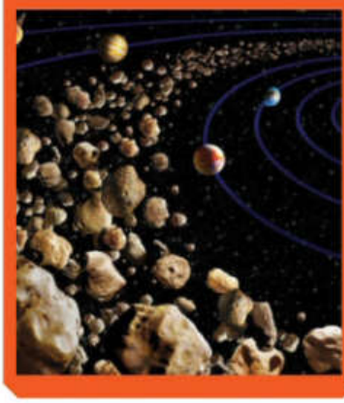


These green parrots have larger and more complex brain structures

FASCINATING FACTS

How big is the Solar System?

The Solar System ends where the Sun's gravity no longer dominates. This point lies just beyond the Oort cloud, a sphere of icy objects about 100,000 astronomical units (or 1.6 light years) away. **AC**



How do carbon monoxide alarms work?

Gillian Rutherford

■ The simplest alarms use palladium and molybdenum compounds that turn black when exposed to carbon monoxide. This is a purely visual indicator, though. For an audible alarm, some detectors use a clear gel that reacts with carbon monoxide to turn opaque. An LED shines through the gel and a photocell sounds the alarm when the gel gets too dark. Other designs harness the way carbon monoxide can lower the resistance in a circuit, either by reacting with a tin dioxide semiconductor or by dissolving into the electrolyte fluid of a special battery. A circuit measures the resistance change and triggers the alarm. **LV**

Do other planets have rainbows?

Murray Todd

■ To produce rainbows, other planets would need two essential ingredients: direct light and an atmosphere containing droplets of a liquid that can refract light. On Earth, we see rainbows when sunlight bounces in and out of droplets of water, but on Saturn's moon Titan, they could form when light hits droplets of liquid methane. Its thick atmosphere, however, means that visible light rainbows would be rare, but infrared rainbows could be common. Titan is the only place in our Solar System where the conditions needed for a rainbow are known to be present – but they might well exist elsewhere in the universe. **AC**

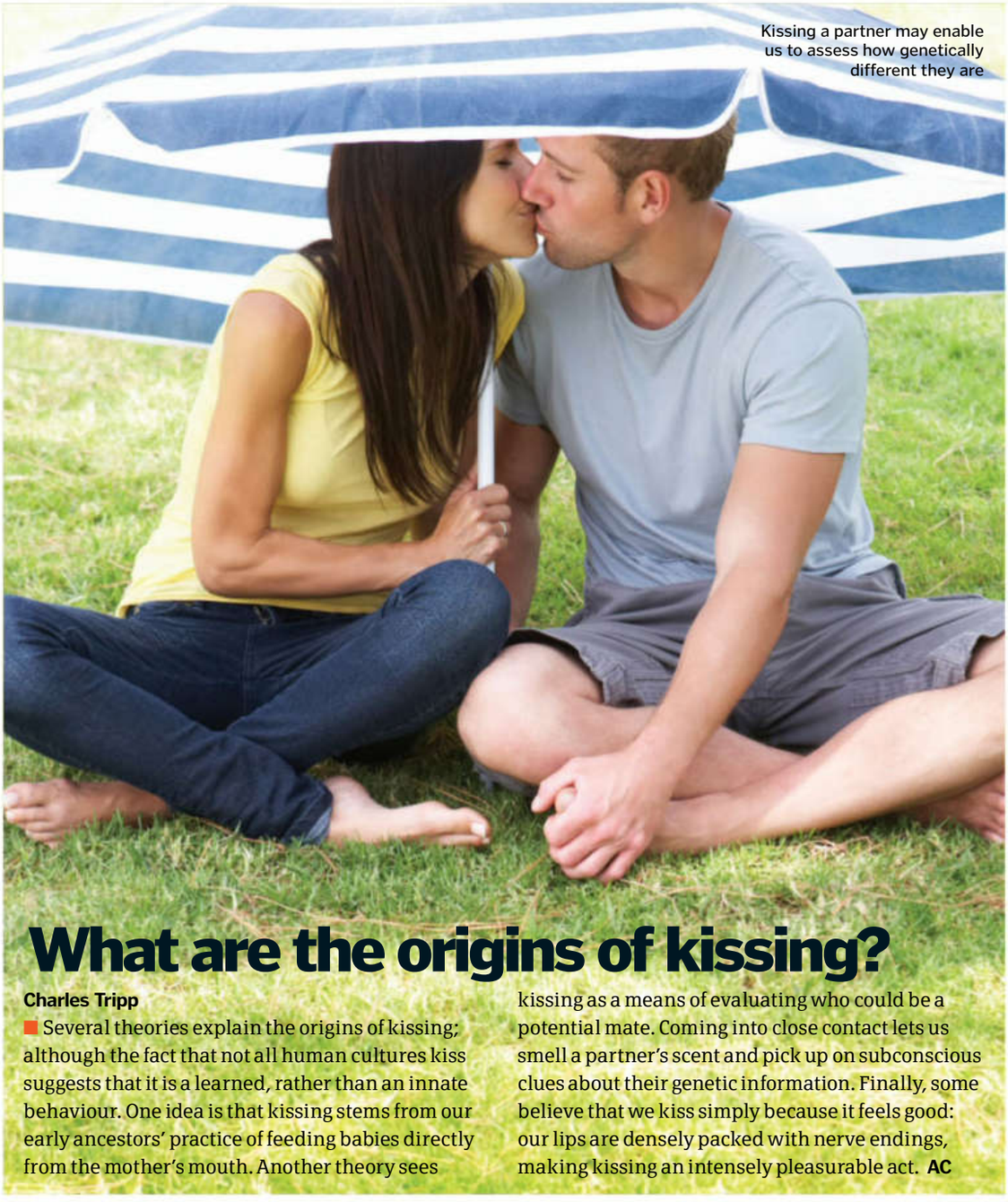
Why does hair get lighter in the summer?

Brad Preston

■ The effect of sunshine on hair is the result of ultraviolet light. The brown and red tones of skin and hair are caused by pigments known as melanin. As the short, high-energy UV wavelengths slam into the melanin pigments, they oxidise. This changes their chemical structure and makes them colourless.

In the skin, living cells respond to this damage by producing more melanin, but there are no living cells in hair. Once the melanin is gone it cannot be replaced, and the result is gradual bleaching. Other molecules in hair can also be oxidised by UV light and as their chemical structure changes, it can make hair rough, brittle and difficult to manage. **LM**

BRAIN DUMP



Kissing a partner may enable us to assess how genetically different they are

What are the origins of kissing?

Charles Tripp

Several theories explain the origins of kissing; although the fact that not all human cultures kiss suggests that it is a learned, rather than an innate behaviour. One idea is that kissing stems from our early ancestors' practice of feeding babies directly from the mother's mouth. Another theory sees kissing as a means of evaluating who could be a potential mate. Coming into close contact lets us smell a partner's scent and pick up on subconscious clues about their genetic information. Finally, some believe that we kiss simply because it feels good: our lips are densely packed with nerve endings, making kissing an intensely pleasurable act. **AC**

Is dark chocolate better for you than milk chocolate?

Robert North

Dark chocolate is better for you than milk chocolate, as it generally contains more of the good stuff and less of the bad stuff. In other words, it has healthy monounsaturated fatty acids, less sugar, more fibre and therefore fewer carbohydrates. It also has much more iron and magnesium, more phosphorus and potassium, less sodium and less cholesterol. It even contains theobromine, which helps lower blood pressure. In addition to this, cocoa found in dark chocolate is rich in antioxidants. It reduces inflammation, which is great for the cardiovascular system and lowers the chances of cardiovascular disease. Plus, bioactive compounds can improve blood flow to the skin and even protect the skin from Sun damage. **SB**

FASCINATING FACTS

How long did it take to build Egypt's Pyramids?

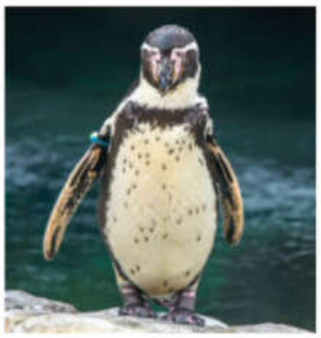
Modern Egyptologists believe that the Great Pyramid was built over a 20 to 40-year period, so it took about 80 years for all three of the pyramids, plus the other monuments that are at Giza. **SF**

Can germs survive on a bar of soap?

Yes. Most soap does not actually kill bacteria; it just helps to wash them off your skin. Microbes can also survive in liquid soap, so keeping dispensers clean is vital. **LM**

Why does my phone suddenly lose signal in places where it was present before?

It's called 'cell breathing'. Mobile phone masts can shrink the geographical area they cover at peak times to maintain bandwidth. If you fall outside the new cell boundary, your signal will suddenly drop. **LV**



Do any animals have belly buttons?

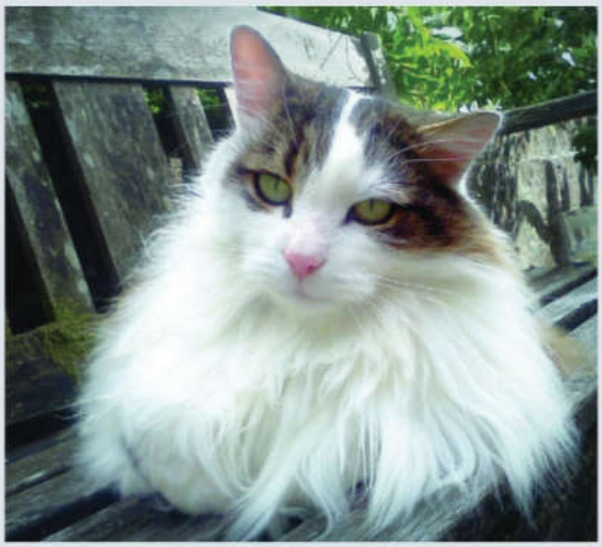
Ron Brigden

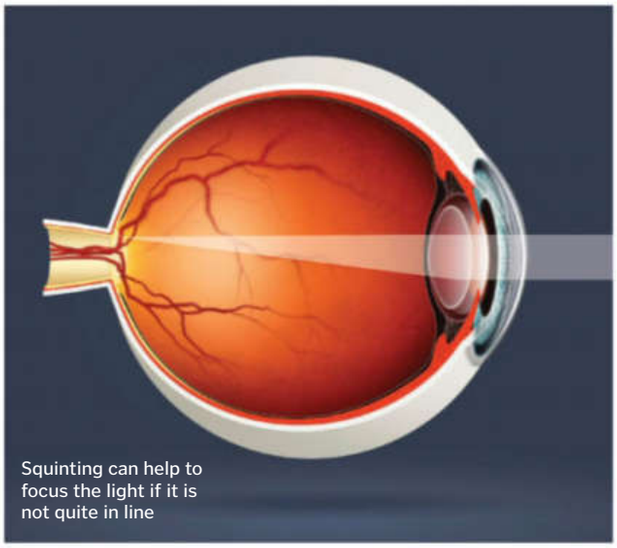
Belly buttons are few and far between in the animal kingdom, but the majority of mammals do actually have them. Since placental mammals are all gestated inside their mothers, they will be born with their umbilical cords still attached. Once they have been delivered, their mothers typically chew through the cord to separate it from their offspring, which tends to leave a flat scar or small bump that is much less visible than a human's belly button. The animal's hair will often obscure their navel further, making it much harder to spot. There are mammals that prove an exception to this rule. Platypuses lay eggs, therefore there is no umbilical cord from which a belly button could form. Marsupials do have umbilical cords, but these usually become detached when they are still inside their mother's pouch. As they are still very small at this stage, a scar never develops into a visible navel. **AC**

Are cats smarter than dogs?

Luke Grey

Dogs can be trained to perform all sorts of useful jobs, but does that mean they are more intelligent or simply more eager to please? A 2010 study at Oxford University found that the ratio of brain size to body size in dogs has been steadily increasing since they were first domesticated eight to ten thousand years ago. That hasn't happened with cats even though they have been domesticated for almost as long. This may be because dogs are social animals, and the extra brain capacity required to keep on top of complex social interactions means that social species are nearly always more intelligent than their solitary relatives. However, cats actually still have almost twice as many neurons as dogs in their cerebral cortex – the region associated with learning and intelligence. Some experiments have shown that cats are just as good at solving puzzles, but this is very hard to test because they simply aren't as motivated as dogs. **LV**





Squinting can help to focus the light if it is not quite in line

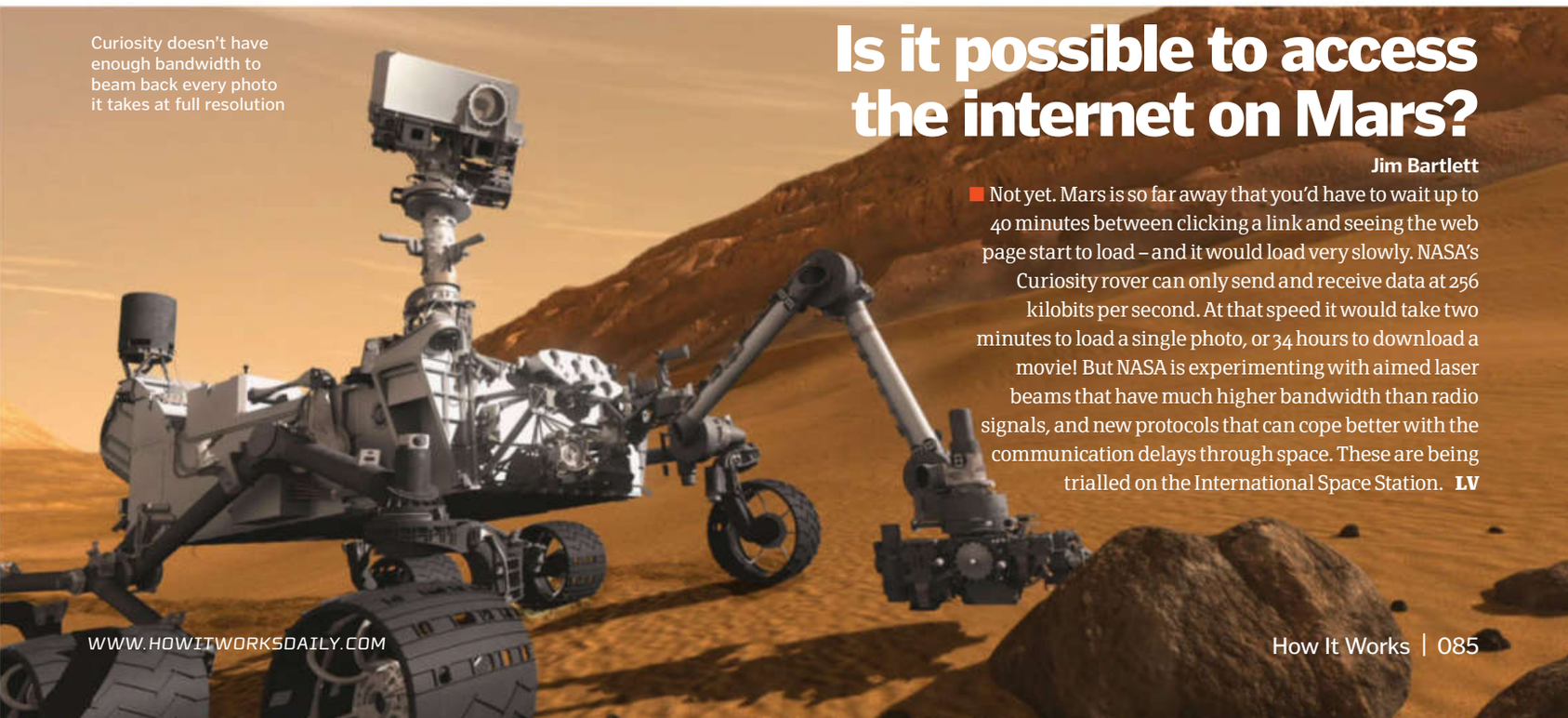
Why can we see clearer when we squint?

Holly Rundle

It doesn't work for everyone, but for some people things come into focus when they half close their eyes. This is because of the way that the eye focuses light.

A flexible lens bends the light as it passes into the eye, focusing it on a highly sensitive spot on the retina, called the fovea. The lens changes shape depending on the distance to the object, ensuring that the light is always concentrated on this spot.

As we get older, the lens becomes less flexible and cannot focus the light as well. By half closing our eyelids, we can put a little pressure on our eyeballs, changing their shape manually and helping to bring the light into focus. **LM**



Curiosity doesn't have enough bandwidth to beam back every photo it takes at full resolution

Is it possible to access the internet on Mars?

Jim Bartlett

Not yet. Mars is so far away that you'd have to wait up to 40 minutes between clicking a link and seeing the web page start to load – and it would load very slowly. NASA's Curiosity rover can only send and receive data at 256 kilobits per second. At that speed it would take two minutes to load a single photo, or 34 hours to download a movie! But NASA is experimenting with aimed laser beams that have much higher bandwidth than radio signals, and new protocols that can cope better with the communication delays through space. These are being trialled on the International Space Station. **LV**

BRAIN DUMP

It turns out that growing pains don't have much to do with growth after all

What are growing pains?

Jane Brice

The medical name for growing pains is 'recurrent nocturnal limb pain in children', and it describes the sensation of aching, crampy pain most often felt at night in the lower half of the legs.

Children and preteens are often told that they experience these aches and pains because they are growing, but this is untrue. If the pain really were caused by growth itself, doctors would expect to be visited by children that were going through a growth spurt, but there does not seem to be any link between periods of rapid bone growth and experience of 'growing pains'.

The pain is not in the bones or joints but is actually in the muscles and soft tissues, and one of the best explanations is that the pain is the result of strain or overuse of the muscles and joints during the day. **LM**

FASCINATING FACTS

Where does the saying 'daylight robbery' come from?

It's a myth that this originated from 17th century window tax, whereby people had to pay tax for every window in their house. It actually refers to the audacity of committing robbery in daylight hours. **SB**

There are many theories as to why pigs tails are curly; the most popular is that they were artificially bred

Why do pigs have curly tails?

Caitlin Hoover

Let's set things straight: only domesticated pigs have curly tails. Wild pigs actually have straight tails. There are a number of theories on why this might be the case. The most unexciting explanation is that there is no real reason. The degree of curliness varies in the sense that some domesticated pigs have a slight kink, whereas others have far more of a curl. Another theory suggests that the curly tail evolved to protect the pigs when fighting each other, as a curlier tail is more difficult to grasp. However, there is a more widely held belief that the curled tail was artificially bred by Chinese farmers because they felt curly tails were more aesthetically pleasing. This is a very popular theory and one that is quite likely, given that the domestication of pigs occurred in China 8,000 years ago, relatively soon after the first domestication took place. **SB**

What's the difference between venomous and poisonous?

Bradley Costa

Both venomous and poisonous organisms can be harmful, sometimes deadly, but the difference between them lies in the delivery of their toxins. A venomous organism injects its venom into other organisms using either a stinger or fangs, which are attached to a gland that produces the venom. The venom is injected often to immobilise prey or protect against potential predators. It is therefore usually always intentional. Poisonous organisms are different in the sense that large parts of them, or often the entire organism, contain toxins. Therefore eating, or even just touching it, can prove harmful. **SB**

The common housefly can hide in the trickiest of spots, like on your ceiling

How do flies walk upside down?

Andrew Hastings

What appears to be a smooth surface, like a ceiling, for example, is actually covered in tiny cracks and bumps too tiny to be seen by the naked eye. These can provide insects like flies with a sort of toehold, or rather, a hairhold. A fly's legs end in clawed segments called tarsi, which have pulvilli, or large footpads, at the bottom. The pulvilli are covered in lots of setae, stiff bristle-like hairs. The setae produce a glue-like goo that lets the fly adhere easily to smooth surfaces, but also enables them to quickly take off. **SF**

Why do birds fly into windows?

Maggie Peak

Unfortunately about half of the birds that collide with windows die, either from injuries caused by the collision itself or by another animal when the bird is stunned and unable to fly away. Ornithologists believe that the birds, which are usually small songbirds, are probably seeing the reflection of trees and open sky in the window, and think that they have a clear flight path. Your local ornithological society can give you tips on how to make your windows bird-safe and what to do if you find a stunned bird that has flown into a window. **SF**

Why are animal transportation laws to Australia so strict?

Alison Wells

Australia has been isolated from the other continents for around 80 million years. That's long enough for it to have evolved many unique species of animals and plants that don't have any natural resistance to bacteria and fungi from other parts of the world. Even non-tropical countries have plenty of diseases that could threaten Australia. If you want to take your pet dog to Australia from the UK, for example, you'll first need to have it checked for rabies, ticks, canine influenza, worms, Brucellosis, Leptospirosis, Leishmaniasis and Ehrlichiosis, before leaving it in quarantine for ten days on arrival. **LV**

Why do bats tend to live in caves?

Samantha Carey

Caves provide bats with a shelter where they can sleep or hibernate with minimal disturbance. Hanging from high ceilings and walls, bats are beyond the reach of most predators but also able to immediately launch into flight if needed. Large caves provide space for whole colonies to roost side-by-side, conserving energy. Caves' stable temperature and humidity conditions are also ideal for hibernation. Bats typically change roosts throughout the year to match their needs when foraging, raising offspring or hibernating. Not all bats live in caves, though; many species roost in trees and others have adapted to living in barns, houses, tunnels and bridges. **AC**

Nail biting, a common habit, is called onychophagia

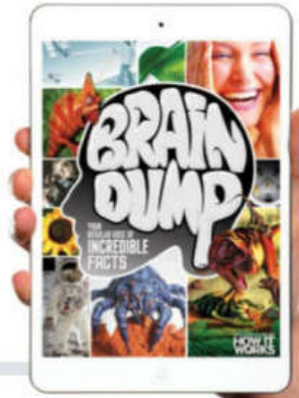
Why are habits so hard to break?

Michelle Kenwright

Some habits are extremely beneficial; the ones that you go through as part of your morning routine before work are a good example of this. Other habits activate the pleasure centres in our brains, triggering the release of a feel-good chemical called dopamine. It doesn't distinguish whether the habit itself is good for us, and repeating habits that release dopamine ultimately changes the way our brains work. That's why addiction has come to be classified as a disorder or a disease, rather than a flaw in a person's character. Knowing that the habit isn't good for you doesn't keep your brain from wanting you to keep it up. **SF**

New Brain Dump is here!

Don't miss issue 28 of **Brain Dump**, the digital sister magazine to **How It Works**, which is available from virtual newsstand now. You'll learn whether eating fish really is good for your brain, how birds know when to migrate, how high a balloon can travel when you let it go and much much more! There are loads more trivia snippets for you to get stuck into, giving you the knowledge hit you need without having to lug an encyclopaedia around! Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is @BrainDumpMag.



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The tech behind the latest must-have gadgets

Gaming gear

The game-changing gadgets that will make your opponents green with envy and ensure you're top of the leader board

Waist harness
The harness rests on the support ring using metal poles to let you move freely.

Concave platform
The concave platform results in a smooth walking motion and reduces any impact on your joints.

Support ring
The harness and ring support your weight to stop you from falling over.

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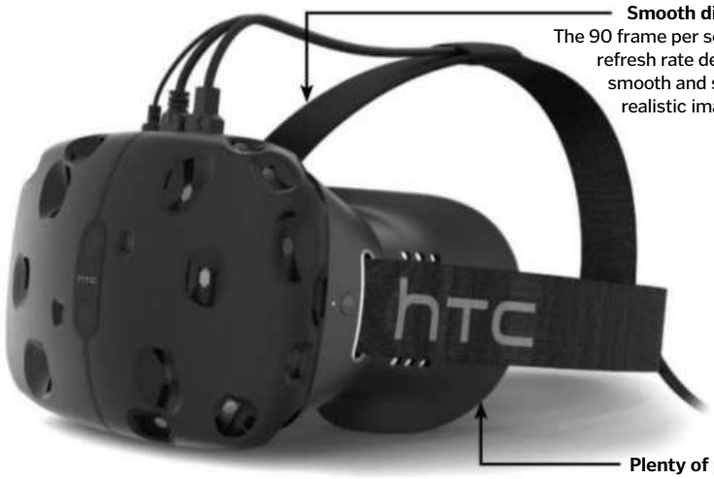
$699 (approx £450)
www.virtuix.com

The Virtuix Omni lets you walk, run, turn and jump in a 360-degree virtual world, for the most immersive gaming experience ever. Once you put on the special low-friction shoes, you can glide your feet across the concave platform, letting the grooved surface and gravity do some of the work to help replicate a natural stride. Then, when you put on your virtual reality headset, you are transported into the game and can move around as your character. It works by wirelessly connecting to your headset or PC via Bluetooth, and then tracking devices on your shoes communicate your movements to the gaming software. The Omni is compatible with any PC game that supports a virtual reality device, but cannot currently be used with console games. To get your hands on one, you can preorder the Omni package now, and it should arrive at your door in late 2015/early 2016.

2 Get behind the wheel

Logitech G29 Driving Force racing wheel
£299 / $399.99
gaming.logitech.com
Get the full driver experience when playing your favourite racing games with this superior console. The wheel features powerful dual-motor force feedback to realistically simulate shifts in weight, understeering or oversteering and tyre slips, so you can respond quickly and effectively. Steering is smooth yet tight for precision control, and sensors in the wheel use magnetic fields to reliably and accurately determine its position. The hand-stitched leather wheel can also rotate 900 degrees, the same as in a real car, and puts all of the control within easy reach of your fingers. A responsive pedal unit helps to complete the driving experience.



Smooth display
The 90 frame per second refresh rate delivers smooth and super-realistic imagery.

Plenty of pixels
The 1,200 by 1,080 pixel screens in front of each eye fill your field of vision.

3 Play in virtual worlds

HTC Vive
TBC
www.htcvr.com
Tech giant HTC has teamed up with Valve, the games company that brought you *Portal* and *Half-Life*, to create a virtual reality headset that will truly get your head in the game. A gyrosensor, accelerometer and laser position sensor track your head position to enable you to look around the 360-degree virtual world, and when paired with special base stations and game controllers, you can move around and interact with objects in the game too. The HTC Vive is currently only available for virtual reality content creators, but a commercial model is due to be released in late 2015.

4 Gain precise control

Razer Mamba gaming mouse
$149.99 (approx £96)
www.razerzone.com
Billed as 'the world's most advanced gaming mouse', this device can be used in either wired or wireless configurations, and features a precise 5G laser sensor to ensure the cursor always stays on target. It also uses Adjustable Click Force Technology, enabling you to freely adjust the click force of the left and right buttons with 14 different settings. This means that you can enable a distinct click for high accuracy shooting scenarios, or a lighter press for rapid-fire action. The sleek ergonomic design of the mouse is also complimented by customisable LEDs, which can be programmed with up to 16.8 million different colour combinations.

EXTRAS

Resources to aid your gaming know-how

BOOK

Videogames Hardware Handbook Vol 2

£9.99 (approx $16)
imagineshop.co.uk
Discover over 20 years of videogame history told through the machines that made it possible, from the Atari 5200 to the very first PlayStation. You'll also learn about the best games available on these classic platforms, including *Space Invaders* and *Super Mario Bros.*

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WEBSITE

NowGamer.com

nowgamer.com
As well as the up-to-the-minute news and reviews covering multiple platforms from the world of gaming, **NowGamer.com** also brings you fascinating features about this exciting industry, and tips for how to master all of the latest games.

5 Stream your gameplay

Roxio Game Capture HD Pro
£129.99 / $149.99
www.roxio.co.uk
If you fancy yourself as the next YouTube gaming star, then this clever device can help get you there. When connected to your PC, TV, PlayStation or Xbox, it can record your gaming footage in HD video and live-stream it, along with your commentary, to YouTube and Twitch tv. Alternatively, you can use the supplied video editing software to enhance your footage with transitions, soundtracks, special effects and more, before sharing it to YouTube or Facebook with one click. The device will even auto-capture up to one hour of gameplay, and tag your best moments so they are easy to find later.

6 Experience high-quality sound effects

Creative Sound Blaster Recon3D Omega Wireless headset
£209.99/ $249.99
uk.creative.com
You can now ensure you hear your enemies coming before they hear you, with this wireless gaming headset. The supplied Recon3D audio enhancer features Scout Mode to enhance even the most distant noises, and creates a 360-degree soundscape to help you hear what is going on in front, behind or above you. This extra accessory plugs into your PC, Mac, PlayStation or Xbox, and connects wirelessly to the comfortable headset for complete freedom of movement. It can stop the speaker's sound frequencies from interfering with the microphone, to ensure there is no echo and that your voice sounds crystal clear.

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Extract your own DNA

Collect a sample of DNA from your cheek cells with this great home experiment

1 Prepare your alcohol

For this experiment to work you need to get some highly concentrated alcohol. This can be easily obtained from your local pharmacy in the form of isopropyl alcohol. The closer you get to 100 per cent alcohol, the better success you will have. Around 24 hours before you start, place your alcohol in the freezer. It won't solidify due its very low freezing point, but needs to be ice cold for the experiment to work.

2 Produce your cheek-cell mixture

Take a generous mouthful of a lightly coloured sports drink and swirl it around your mouth. Aim to keep this going for a minimum of two minutes, which is a lot harder than it sounds. To get as many cheek cells and therefore as much DNA as possible, gently scrape your cheeks with your teeth. Be careful though, we don't need any blood for this experiment!

3 Set up your test tube

Spit the mixture into a paper cup and pour the solution into a small, clean jar or a test tube, filling it by one third. Add a little dish soap, fasten the lid and then carefully mix the solution, slowly turning it upside down. The soap breaks down the cell membranes, releasing the DNA. Add a few drops of pineapple juice and repeat the process, ensuring you don't create any bubbles.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

4 Add your chilled alcohol

Remove your alcohol from the freezer and take the lid off your mixed cheek-cell solution. While tilting the container in one hand, trickle the alcohol down the inside of the container so that it gradually forms a layer that floats on top of the solution. Once you are happy that a good layer has formed, slowly return the test tube to an upright position and then leave on a flat surface for one minute.

5 Extract your DNA

Once one minute is up, look at the alcohol layer floating on top of the solution. If you can see a band of white material between the alcohol and the rest of the solution, your experiment has worked! This is your DNA, and it can be extracted using a wooden skewer. Dip the skewer into the solution so that it touches the white material, and then twirl it slowly in one direction. This should wind the DNA around your skewer. You can now store your DNA in the freezer or examine it using a microscope!

In summary...

Gentle mixing of the soap and sports drink solution makes sure that the DNA clumps don't break up, which makes the extraction process much easier. This experiment relies on the fact that DNA does not dissolve in alcohol, which forces it to precipitate out from the sports-drink solution when this contacts the alcohol layer.

NEXT ISSUE
- How to build a nuclear shelter
- Make a working heart chamber

Make sugar crystals

Study the formation of crystals and make a tasty treat!

1 Prepare your sugar solution

Start off by boiling some water using either a kettle or a pan. Ask an adult to help you with this just in case of any accidental spillages. Once you've got your boiling water in a pan, carefully add sugar one spoonful at a time, making sure that you don't touch the pan or cause any of the boiling water to splash around. It's key that you have as much solute dissolved in the solution as possible, as this will increase the chances of your crystals forming.

2 Set up your glass jar

Once you're satisfied that you've dissolved as much sugar as possible, add a few drops of red food colouring to give your rock candy some colour. Being extra careful, pour the solution into a clean jar (it has to be clean as otherwise sugar crystals will bind to any dirt in the jar). Tie a piece of string around a butter knife, making sure it is long enough to hang into the solution but doesn't touch the bottom or the sides of the jar.

3 Leave to grow

The set up of your jar is now complete and needs to be left for a week to allow the crystals to grow on the string. We recommend that you leave your jar in a safe, dry area, where it won't be exposed to lots of dust or debris. It's also vital that the jar isn't knocked or moved in any way, as this would disrupt crystal formation on the string. Once you are happy with their growth, lift the knife up and remove the crystals. When they are dry, this colourful sweet treat is ready to enjoy!

In summary...

The substance you've created is essentially a primitive form of rock candy. The crystals grow due to their tendency to clump together at a molecular level, which happens when they bump into each other in solution. This process is known as nucleation, and will readily occur in solutions that contain high concentrations of solute.

Illustrations by Edward Crooks

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Letter of the Month

The science of dizziness

Dear **HIW**,
I really enjoy your magazine; it covers so many different topics in lots of detail! I want to know why spinning around makes us go dizzy, as I've never quite understood how it works! I hope you get the chance to answer my question.
Many thanks,
Will Haynes (aged 11)

Hopefully we can help you out with this, Will. The feeling of dizziness is related to your sense of balance that is regulated by a clever system inside your inner ear. This is called the vestibular system, which normally works to sense orientation by detecting gravity. When you move your head, the fluid trapped inside this upper portion of the inner ear presses against the receptor cells. They then tell the brain that you are moving and that it needs to prepare your body to adapt to this. If you move your head very quickly and then suddenly stop, the fluid will continue to move and provide a false sense of movement, which is essentially what dizziness is.

This is also why we don't tend to feel dizzy until we actually stop spinning. Occasionally an ear infection will alter your sense of balance more permanently, making you constantly dizzy while stationary, which is a particularly unpleasant sensation.

Your ears are responsible for more than just hearing; they also sense orientation

Identical fingerprints?

Dear **HIW**,
I live in Canada and I love your magazine! My question is: why do identical twins have different fingerprints when they match at a genetic level?
Thanks,
Jessica (aged 12)

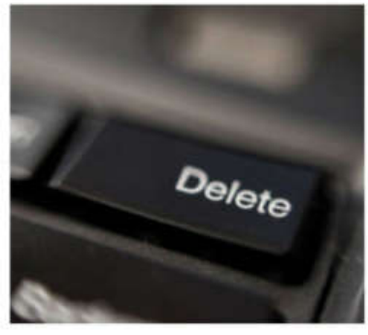
That's a great question, Jessica. Although fingerprint patterns (such as whorls, loops and arches) are likely to be genetic, fingerprints differ – even between identical twins – because they are influenced by more than just genetic coding. The fine details of the ridges, valleys and swirls that define our unique fingerprints are set during the first few weeks of our development. They are influenced by factors such as our exact position in the womb, random stresses that we experience, as well as chance fluctuations in hormone levels that are very common during pregnancy.

They may possess identical DNA, but a fingerprint comparison is a sure-fire way to tell identical twins apart

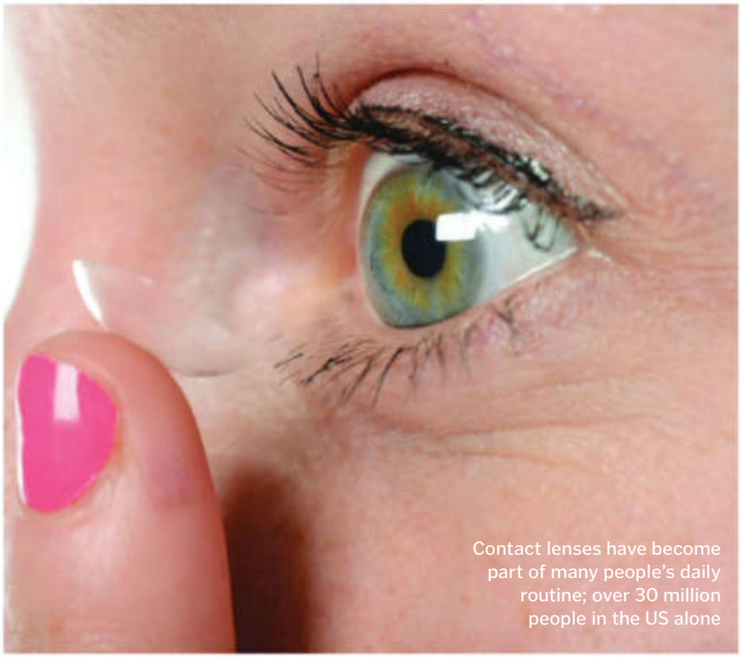
What happens to deleted files?

Dear **HIW**,
I've been wondering what happens to computer files when you click delete? Where do they go? I hope you can answer my question so I can get published in your wonderful magazine!
Thanks,
Anastasia Norambuena (aged 12)

When you first delete a file, it moves to the computer's trash or recycle bin, where it remains easily recoverable. When it is deleted from this location, all the computer is doing is removing the file's header, so that the computer can no longer read it. The file can still be recovered at this point and will not be deleted until it is overwritten by a brand new file, which may not be for a while depending on the size of the hard drive.



A skilled computer technician can easily restore deleted files using specialised data recovery software



Contact lenses have become part of many people's daily routine; over 30 million people in the US alone

"Leonardo da Vinci came up with the concept of the contact lens over 500 years ago"

How do contact lenses work?

Dear **HIW**,
I've just started wearing contact lenses, and was hoping that you could explain to me how they work and who came up with the idea?
Thanks,
Josh Meegan (aged 14)

Contact lenses provide more natural eyesight than glasses, as they are directly in contact with the eye, hence their name. Designed to maintain ocular health and correct the eye's refractive errors, contact lenses float on the cornea's surface – the tear film layer. They work by refracting (or bending) light, so that it focuses into a single point on the retina at the back of the eye. The shape of the lens differs based on the type of vision problem it needs to correct. Leonardo da Vinci came up with the concept of the contact lens over 500 years ago, but it wasn't until 1960s that the soft contact lens was introduced.

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@HowItWorksmag fantastic front cover on the Red Arrows – would love to know more after attending the RAF International Tattoo last weekend!

@Sm1ther33ns
Can't wait to read my **@HowItWorksmag**

@pressxtoskip
Didn't know you were making videos **@HowItWorksmag**, love it!

@EugenesDIYDen
@HowItWorksmag I love dinosaurs! Your '10 facts about dinos you (probably) didn't know' article is brilliant!

@cjayp33
Nice surprise when home from work, as the next issue of **@HowItWorksmag** waiting. Looks another fascinating issue.

@Neiltyson
Ancient Geek Proverb: To be a genius is to be misunderstood. But to be misunderstood is not to be a genius.

@ProfBrianCox
Pluto is red! It's so wonderful to be able to witness the exploration of a new world.

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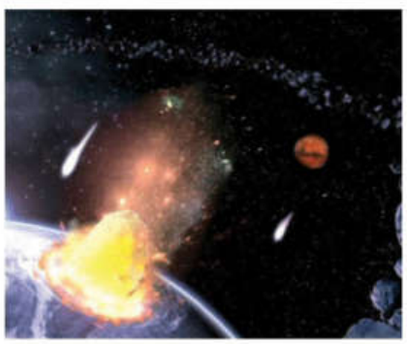

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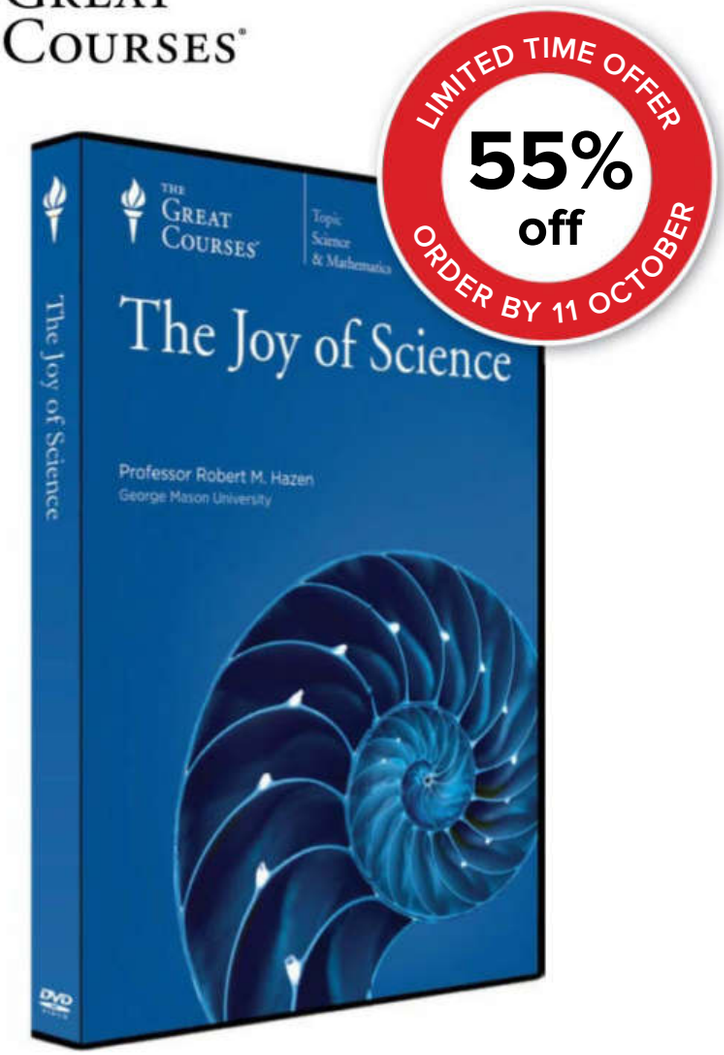

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